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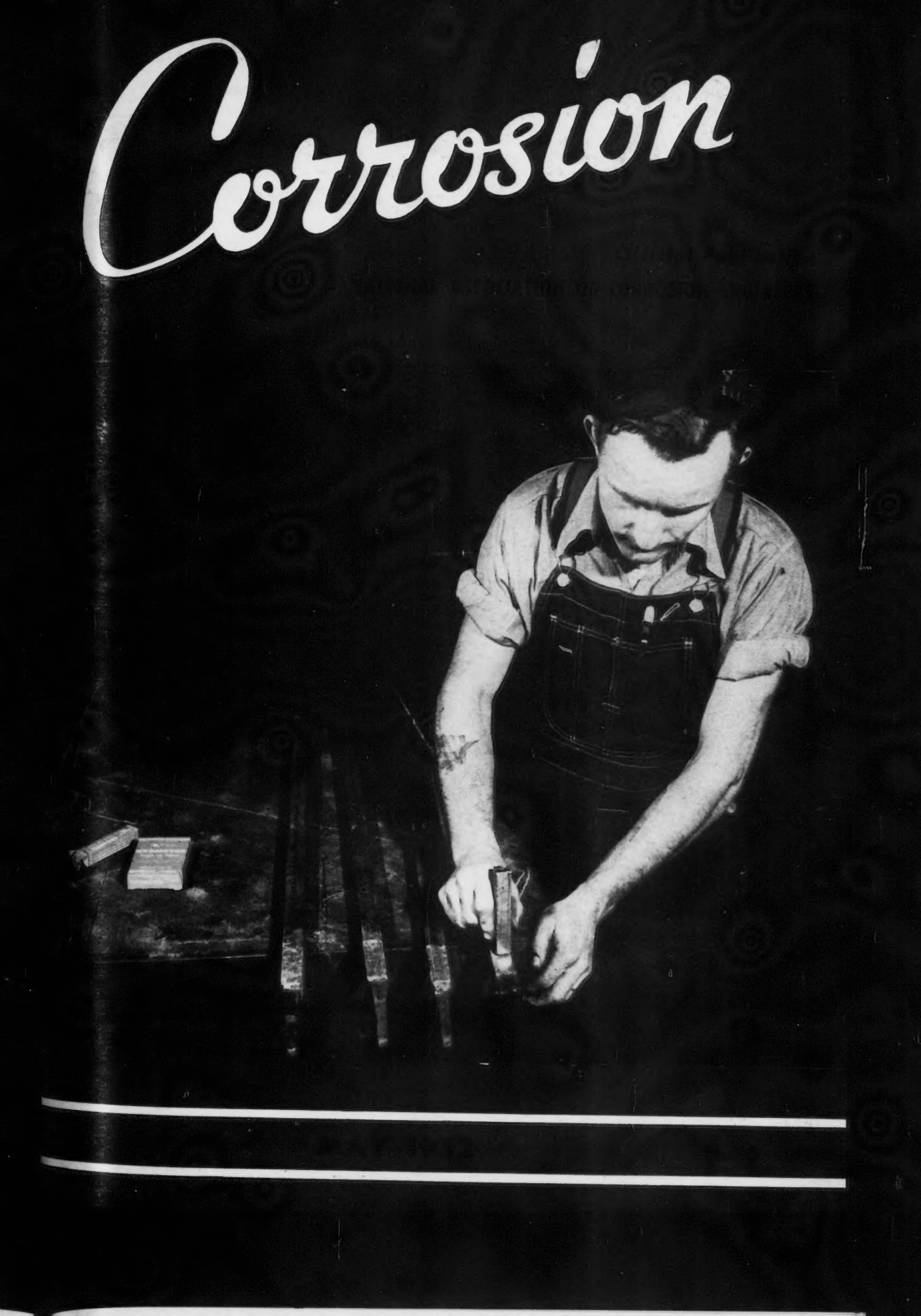

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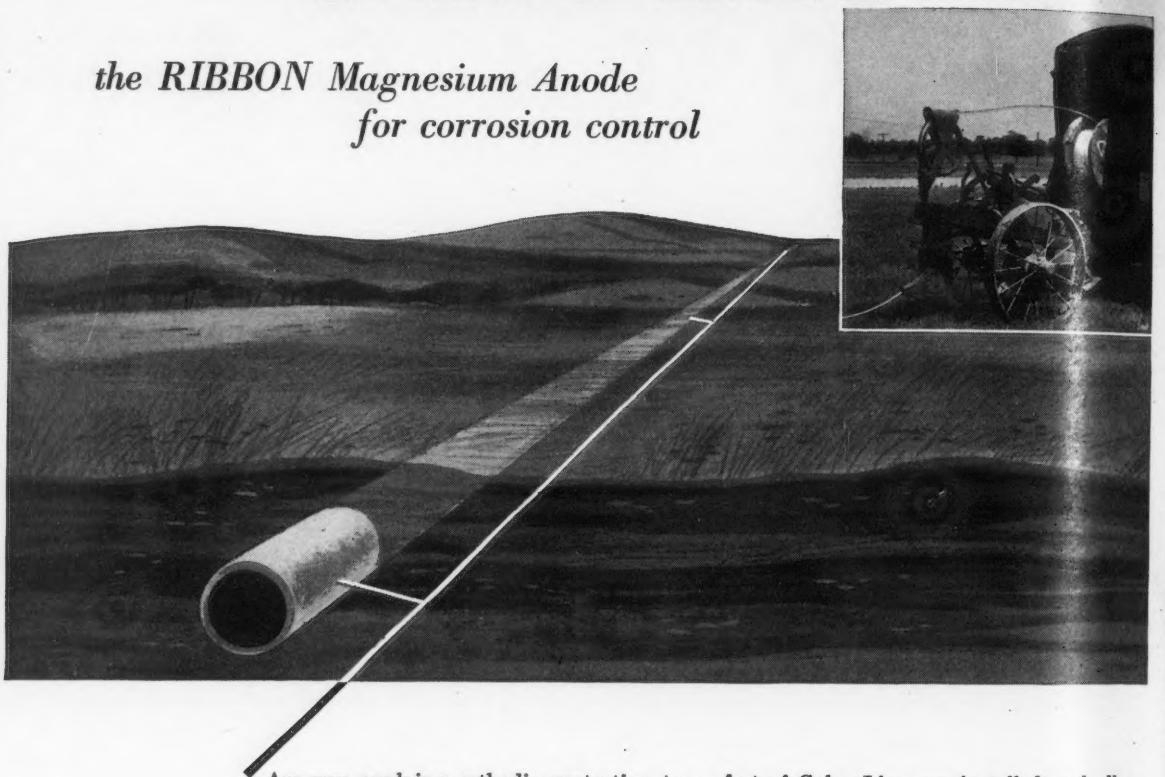

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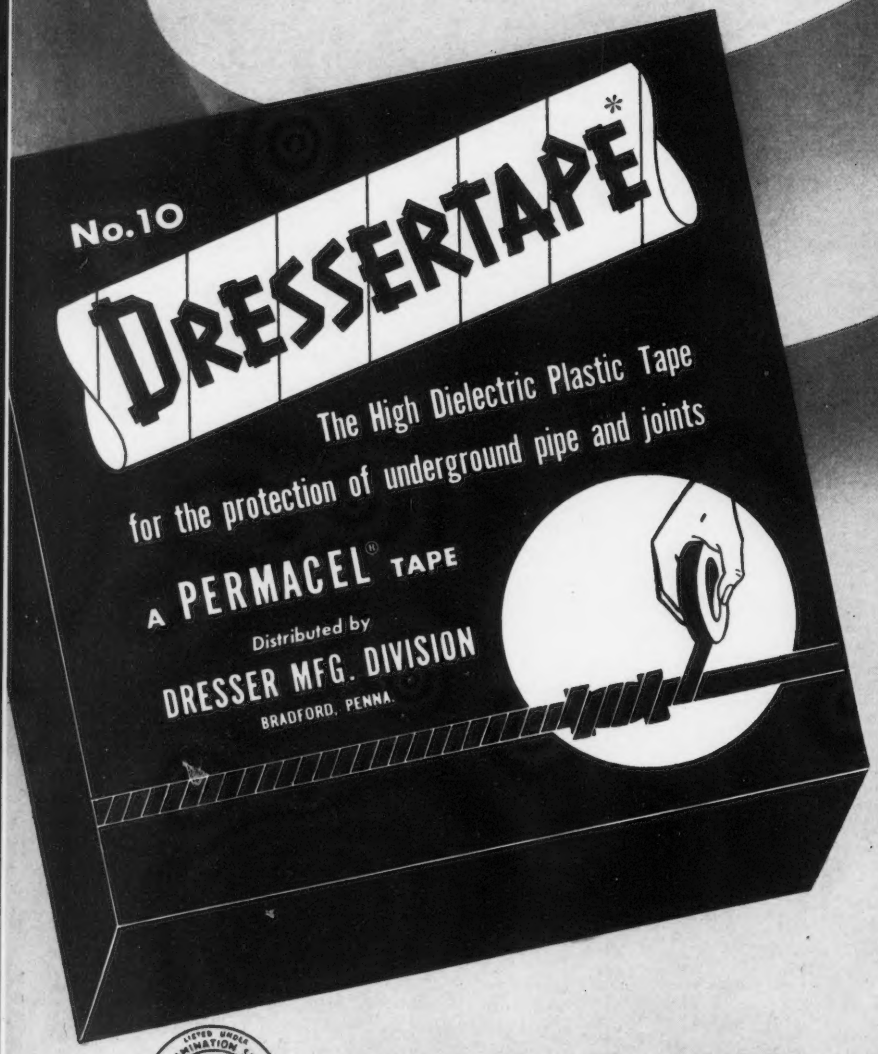

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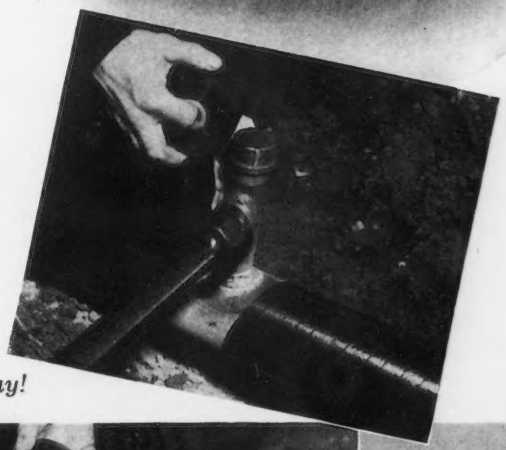

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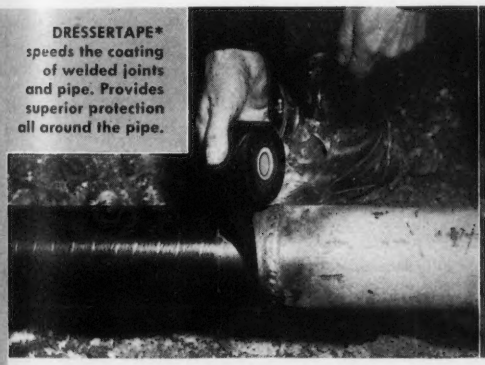

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(Continued from Page viii)

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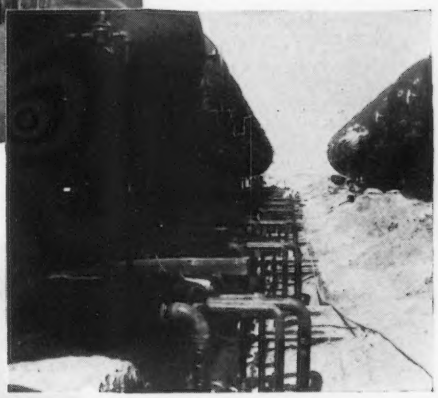

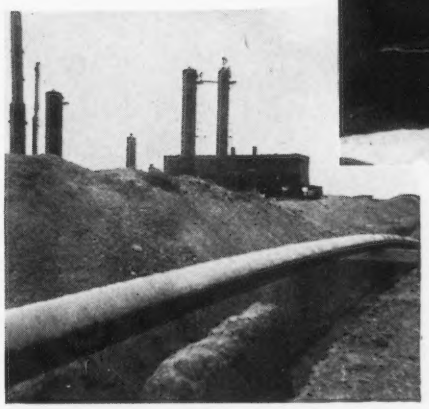

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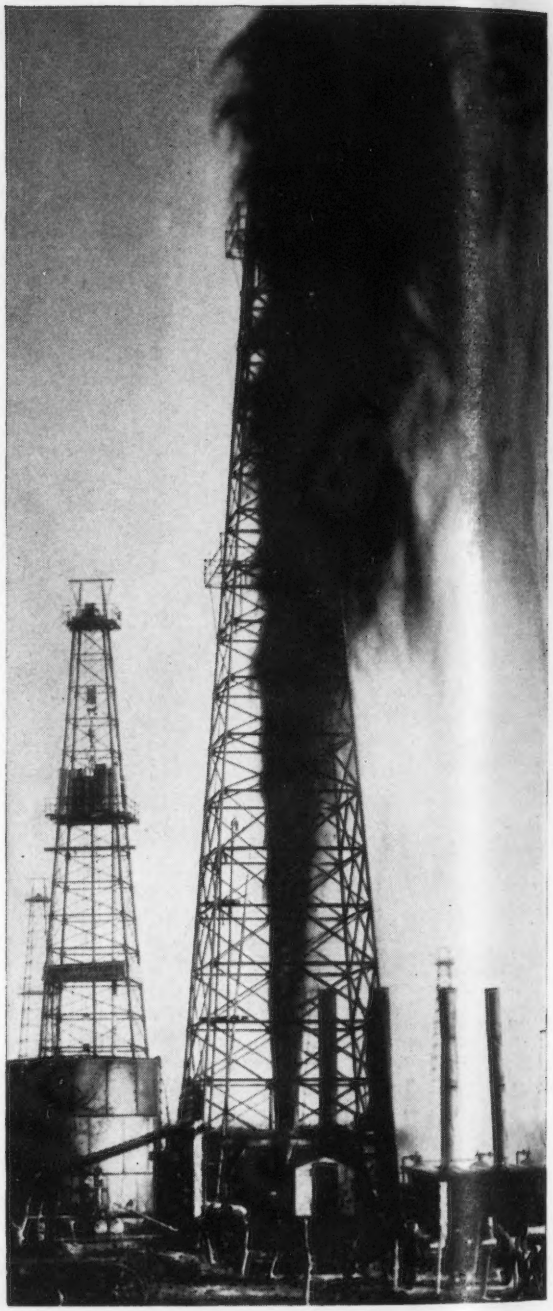

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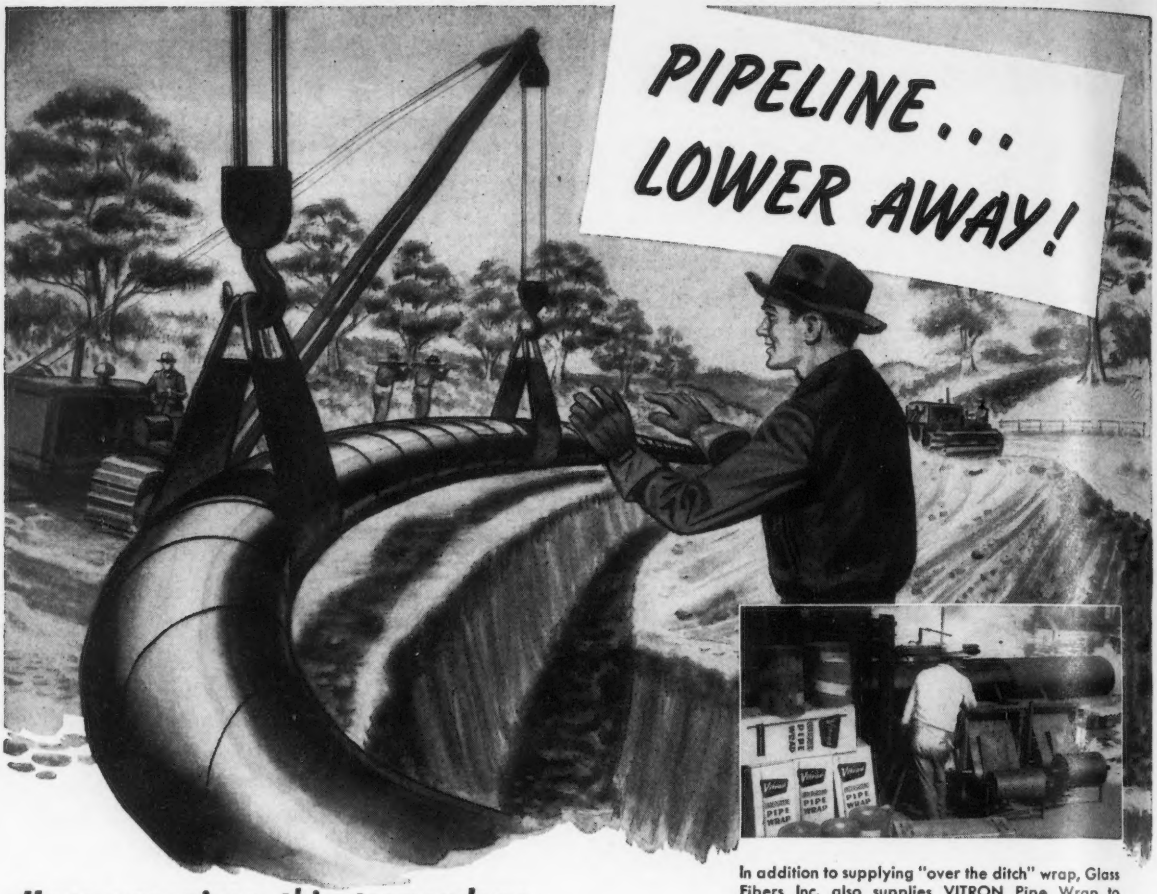

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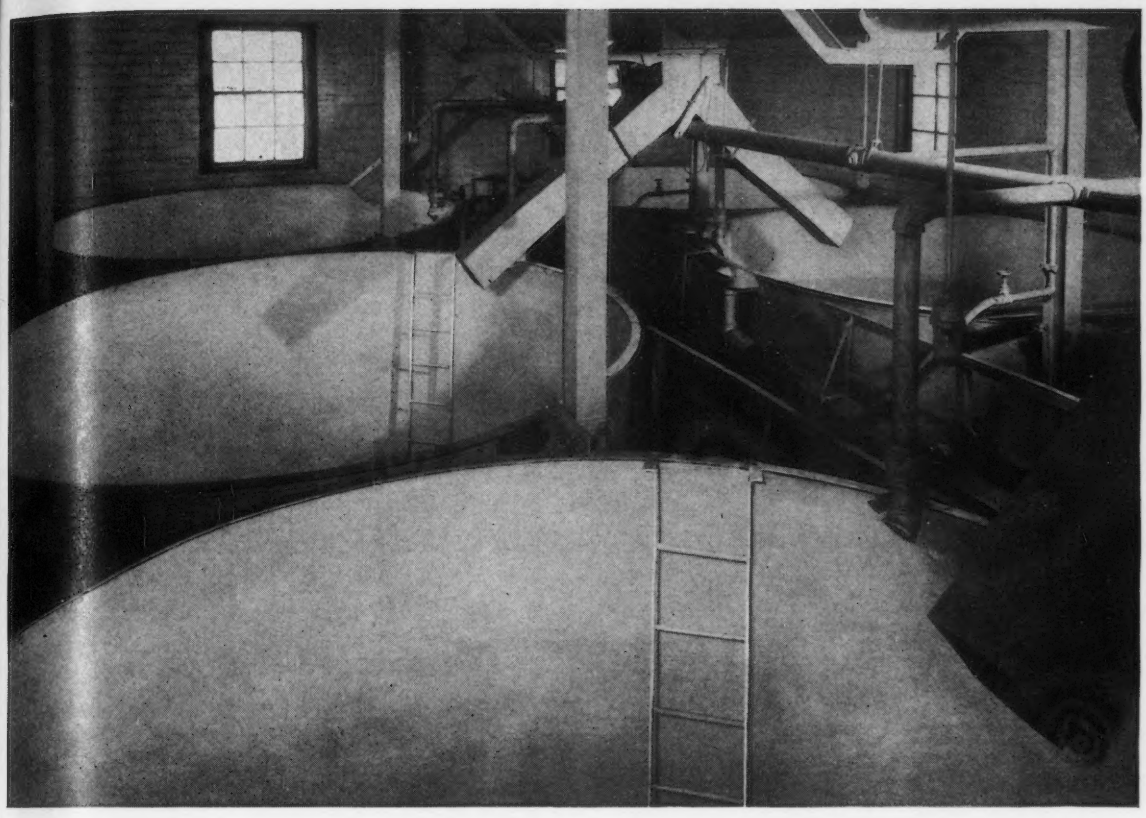

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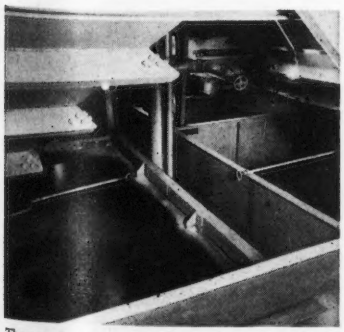

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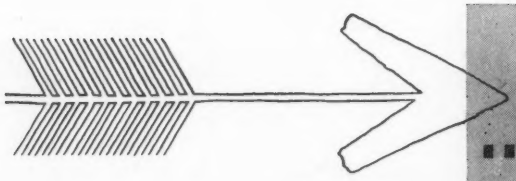

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is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.

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Corrosion

OFFICIAL MONTHLY PUBLICATION

National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

919 Milam Bldg. Houston 2, Texas

Vol. 8 May, 1952 No. 5

The Inter Society Corrosion Committee

By SAM TOUR*

Sam Tour & Co., Inc., New York, N. Y.

IN THE LATE THIRTIES, before the National Association of Corrosion Engineers came into being, the American Coordinating Committee on Corrosion was organized. That committee was made up of representatives from many of the technical societies, scientific organizations and governmental agencies of the country interested in and actively working in the field of corrosion. Dues paid by the member organizations provided funds of less than $2000 per year for the operation of the committee. In addition to the functions now being performed by the Inter Society Corrosion Committee, the ACCC—

1) Prepared and published a directory of corrosion, workers in the United States,
2) Sought for some organization that would publish a magazine devoted to the subject of corrosion,
3) Negotiated for the development of a better abstract service to cover the world-wide literature on corrosion,
4) Promoted the giving of courses and educational lectures on corrosion at universities and colleges,
5) Acted as an advisory body to certain governmental defense agencies and undertook special projects for them.

With the establishment of the NACE, its membership lists, its magazine CORROSION and its abstract section, and its committee on education provided the answer to the first four objectives of the committee. With the coming of the armistices, the work of the committee in the fifth objective had come to a conclusion.

To solve the problem of funds necessary for the secretarial work of the ACCC, an agreement was made that if the ACCC would disband and turn over its records and remaining funds to the NACE, this new organization would sponsor and provide secretarial services for an Inter Society Corrosion Committee to carry on the work. The by-laws of the NACE were amended to provide for this change.

The Inter Society Corrosion Committee was organized in the fall of 1948, at a meeting at which representatives were present from eleven different technical societies and three different government agencies interested in corrosion. At that meeting, presided over by Frank L. LaQue, then president of the National Association of Corrosion Engineers, a general form of organization and method of procedure was agreed upon. The committee began to function with an official membership consisting of delegates from 17 different organizations.

H. H. Uhlig was elected as the first chairman of the committee and presided over its affairs for two years until April 6, 1950, when Sam Tour was elected chairman for two years. On March 13, 1952, H. P. Godard became chairman and R. M. Wick, vice-chairman for the succeeding two years.

During the above period, the committee has—

1) Met annually,
2) Adopted by-laws,
3) Gathered, compiled and had published extensive reports from its membership on the Corrosion Research Activities currently under way in North America,
4) Encouraged the continuation of research work on Underground Corrosion of Pipes,
5) Undertaken a survey, on request of a member body, of current interest and activities in the field of bacteriological corrosion,
6) Undertaken a similar survey in the field of the Internal Corrosion of Pipes Carrying Potable Water,
7) Organized various sub-committees to deal with the specific problems outlined in its by-laws as its "Objectives and Slope." These will be described below.

The ISCC membership (at present there are 30 different organizations represented), is under a membership subcommittee of five delegates. The scope of this sub-committee is as follows:

1) To determine whether organizations now represented on the committee are qualified to appoint delegates on the basis of By-Laws II-1, 2 and 3.
2) To recommend to the committee that delegates from organizations that do not qualify for membership be withdrawn.
3) To recommend that qualified organizations, which have not appointed delegates to the committee, be invited to appoint delegates.
4) To evaluate the qualifications of organizations that request permission to appoint delegates to the committee.

The matter of Standard Definitions and Terminology in the fields of corrosion is under a sub-com-

* Immediate Past President, Inter Society Corrosion Committee.

mittee consisting of delegate members special representatives appointed by several technical societies with major interests in the field of corrosion. The scope of this sub-committee is as follows:

1) The preparation of a glossary of terms used in corrosion technology.
2) The keeping up to date of this glossary by an annual report containing changes and additions.
3) The supplying of this glossary and changes in it to the member organizations.

The ISCC sub-committee on Relations with Foreign Technical Organizations is undertaking work along the following lines:

1) The establishment of a list of foreign correspondents associated with foreign technical organizations engaged in corrosion work.
2) The development of means of interchange of published technical information with these correspondents.
3) The dissemination to the members of the ISCC of such technical information as is received.
4) Assistance to incoming foreign visitors who are active in the field of corrosion in making contacts with their counterparts in North America.
5) Providing such information as may be available to American corrosion specialists, intending to travel abroad, as to persons and places of importance to visit.

Another sub-committee of the ISCC has as its duty the provision of information pertaining to the scheduling of conferences and conventions in the field of corrosion. To avoid conflict of meetings, to promote attendance at meetings and to keep everyone concerned fully advised as to where, when and about what meetings are to be held, this sub-committee will gather the information for publication in the regular issues of CORROSION.

It is hoped that in the near future the annual reports of the ISCC will become, in fact, rather complete directories of the corrosion research projects currently in progress under the leadership of the many technical societies and organizations represented on it. Such complete summaries each year will promote progress of all and avoid excessive duplication of effort. Such an adequate compilation kept up to date will permit the ISCC to recommend in which society a proposed new activity might best be carried out without, however, attempting to define or limit the field of activity of any society.

All of the work of the ISCC is intended to stimulate the publication of corrosion data, disseminate information on corrosion and promote recording of experience by engineers and scientists in the field and in the laboratory.

NACE Requirements on Acceptance and Publication of Papers

(Quoted from "Guide for the Preparation and Presentation of Papers." National Association of Corrosion Engineers, 919 Milam Bldg., Houston 2, Texas.)

These instructions and suggestions govern preparation of papers for publication in CORROSION, and for presentation at meetings of the National Association of Corrosion Engineers. Papers may be submitted for consideration without invitation.

Papers submitted are subject to the publication rules and policies of NACE until released, or unless withdrawn by the author prior to presentation or publication. Papers shall not be a rewrite of material presented elsewhere. The same material shall not be rewritten for presentation or printing elsewhere, except that in some cases an article may be rewritten and pointed toward a particular industry without coming under this restriction. After publication in CORROSION, it is the policy of the Association to give permission to reproduce CORROSION articles verbatim. Such permission shall be requested in writing. Full credit must be given NACE as the original source.

Mercury and Its Compounds— A Corrosion Hazard*

By M. H. BROWN,* W. W. BINGER* and R. H. BROWN**

Abstract

Frequently cases of severe corrosion have been encountered with equipment fabricated of non-ferrous alloys that have long been considered standard for handling or processing a specific chemical. A review of the service history of such cases usually reveals the following pattern: 1) The equipment has functioned for considerable and even long periods of time without evidence of harmful corrosion; 2) Suddenly, in a relatively short time, severe attack occurs. Routine examination failed to disclose the reason for the failures of equipment having such service records. Modified techniques for the examination of equipment having such histories of service reveal, in most cases, the presence of mercury in either the corrosion products, or on the metal surface in the vicinity of the attack, or in the environment. This observation instigated a series of studies on the role of mercury and its compounds in promoting corrosion of metals, the concentration levels that might cause serious attack, and the manner by which such substances could be transported through chemical equipment and plants. It was found that the vapor pressure of metallic mercury even at low temperatures is sufficient to permit the mercury vapors to pass through the system and alloy with many commercial metals. This amalgamation of such metals can result in stress cracking or severe corrosion. It has been shown that metallic mercury reacts with many environments to a sufficient extent to produce compounds that are corrosive to commercial metals. It has been demonstrated that concentrations of mercury compounds as low as 0.5 ppm constitute a serious corrosion hazard for a variety of useful metals and alloys. The results of laboratory work and service experience have demonstrated that mercury contamination, either metallic or its compounds, constitutes a serious corrosion menace. It is believed that control of mercury contamination could easily be justified by the savings that would result from reduced replacement and maintenance of chemical process equipment.

Introduction

CASES OF SEVERE corrosion are frequently encountered in equipment fabricated of alloys that have been established by years of service experience as standard materials of construction. A review of the service records of the corroded equipment has revealed a general chronological pattern. In most cases the records showed that the equipment had demonstrated satisfactory resistance to corrosion for a considerable period and then severe corrosion or failure occurred suddenly. It was also found that the attack was usually highly selective. Not only was the corrosion localized, but the attack was also often limited to a single component part of the entire piece of equipment or one part of several identical parts. For example, only a single or a few tubes of a heat exchanger bundle were attacked, or a small section of heating coil or tank wall showed corrosion.

Although considerable effort was expended over a period of years without finding a satisfactory explanation of the cause of the corrosion behavior, modification of methods finally demonstrated that mercury or its compounds were present in many cases. Indeed, the frequency of detection indicated that mercury or its compounds constitute a serious corrosion hazard in many chemical plants. For this reason, in addition to careful examination of samples from equipment, a laboratory program was undertaken to demonstrate the role of mercury and its compounds in promoting corrosion of chemical equipment. Although the harmful effects of mercury and its compounds on a number of non-ferrous metals are well known, it was decided to determine the concentration levels that might cause serious attack and the manner by which these substances could be transported through chemical equipment and plants.

Typical Experiences From Service

It is not unusual to encounter corrosion of equipment where the underlying cause of the attack remains unknown, even after considerable exacting research. Such a situation is most disconcerting, especially when a successful and long service record is available regarding a given alloy for a specific application and closely related uses.

Although the primary interest was the service experience obtained on aluminum alloy equipment, samples of other non-ferrous alloys which had failed in service were also examined. Several cases are cited below describing the typical experiences encountered.

Steam Unit-Heater

Copper finned brass tubes have been employed in one of the standard types of construction for unit heaters. One of these units was installed in a chemical plant and connected to the plant steam line. Within a few hours several of the tubes had failed by cracking. A representative section of the heater is shown in Figure 1. In view of the fact that copper-base alloys have an excellent performance record in steam service, this failure was most surprising. Upon examination of the tubes, mercury contamination was detected in the areas containing the cracks. The unit was replaced by a similar unit which has been in service for approximately two years and no difficulty has been encountered.

★A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952.

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**Chief, Chemical Metallurgy Division, Aluminum Research Laboratories, New Kensington, Pa.

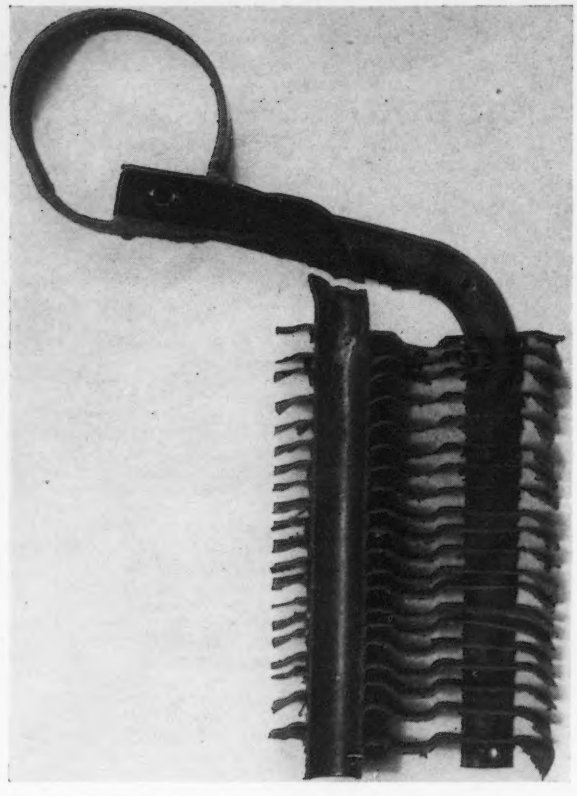

Figure 1—Brass tube (½-inch dia.) in a steam unit heater that cracked after a few hours service. Mercury was detected in the vicinity of the failure.

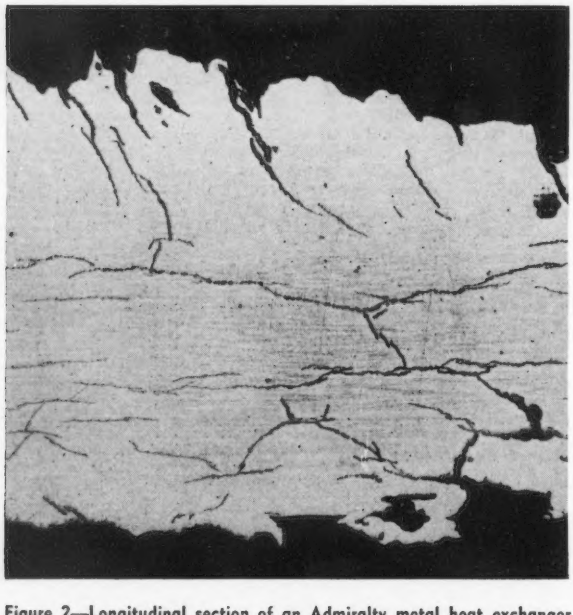

Figure 2—Longitudinal section of an Admiralty metal heat exchanger tube that failed in service when exposed to hydrocarbons. This area was found to contain mercury. The intergranular penetration was caused by mercury which was found on the affected area (10X; unetched).

Condenser

A bundle of Admiralty metal tubes was removed from a condenser because of tube cracking. In this service cooling water passed through the tubes and hydrocarbon gases contaminated with hydrogen sulfide contacted the outside.

A visual examination revealed that the outside of the tubes were roughened and a closer inspection revealed numerous small longitudinal cracks. A metallographic examination of the tube section shown in Figure 2 revealed that the cracks followed the grain boundaries. An analysis of the area containing the cracks revealed the presence of a trace of mercury.

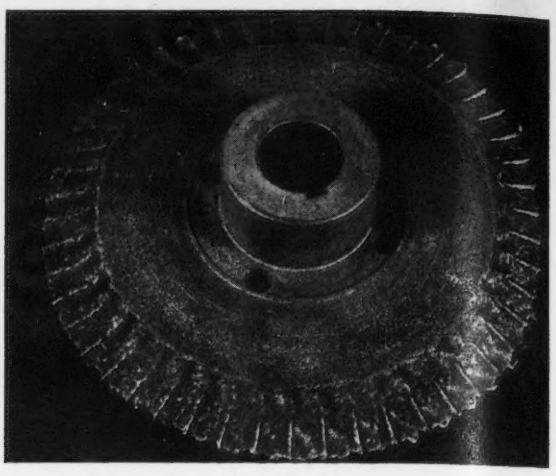

Figure 3—A bronze pump impeller that failed because of severe corrosion of the vanes in three months service in triethylene glycol. Analysis of the surface layers of the impeller showed substantial amounts of mercury.

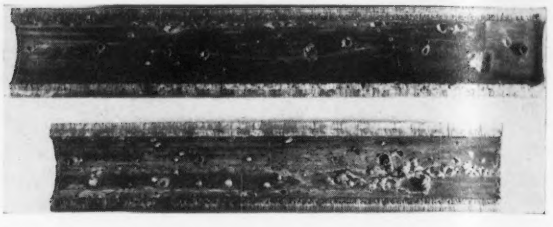

Figure 4—Localized attack in lead lining (⅛-inch thick) of a lined steel pipe (1⅝-inch dia.) after only three months service handling cooling water. Mercury was detected in the pits.

Figure 5—Pitting of an aluminum alloy 52S storage tank (⅜-inch wall thickness) handling glacial acetic acid. Analysis of the surface in this area and of the acid revealed the presence of mercury. Approximate size of section photographed was 3 inches x 13 inches.

Pump Impeller

A bronze impeller used in a pump handling triethylene glycol solution was submitted for examination. As can be seen in Figure 3, the blades had been completely corroded away in only three months' service. An analysis of the surface of the impeller revealed the presence of a substantial amount of mercury.

Cooling Tubes

In one plant the cooling water feeding the heat

exchangers was found to be particularly corrosive to steel tubes. In an attempt to overcome this problem, lead-lined steel pipes were installed. After only three months' service it was found that the lead inner liner was severely pitted (see Figure 4) and almost perforated. An analysis of the surface of the lead liner revealed the presence of mercury contamination. It is believed that the presence of mercury was, at least, a contributing factor causing acceleration of the pitting attack.

Storage Tank for Acetic Acid

Aluminum alloys have been used in the fabrication of storage tanks for glacial acetic acid for over twenty years, not only because of their excellent resistance to corrosion, but also to maintain the water whiteness of the acid.

Recently an examination was made of a 14,000 gallon glacial acetic acid storage tank that was perforated along each side in line with the two steam heated pipe loops welded to the outside of the tank. The general appearance of the corroded areas is shown in Figure 5. A metallographic examination of these areas revealed no change in the microstructure brought about by the welding operation that would alter the corrosion resistance of the 52S aluminum alloy used. Analysis of scrapings from the pitted areas revealed the presence of mercury. A sample of the acid taken from the storage tank was also analyzed. The acid concentration was found to be 98 percent (by wt.) and contained 0.94 grams per liter of dissolved solids. An analysis of the ash of the dissolved solids (0.4 grams per liter) revealed that the mercury concentration was something less than 0.01 percent of the ash, or in other words, a final concentration level of about 0.04 part per million. The corroded areas were cut out, the tank repaired and put back in service. Following this incident, the customer analyzed each new lot of acetic acid for mercury before accepting it. This procedure has been followed for over a year and none of the acid has been found to be contaminated with mercury; as expected, no further corrosion has occurred on this tank.

Storage Tank for Ammonium Nitrate

Aluminum alloys are well recognized as standard materials of construction in the manufacture of ammonium nitrate. In addition, during the past several years approximately 700 aluminum alloy tank cars have been built for the transportation of ammonium nitrate solutions.

In view of this excellent service record, it was surprising when a section of the bottom of a tank constructed of 2S aluminum alloy (see Figure 6) was received for examination to determine the cause of the severe corrosion that perforated the bottom. This tank had been used for the temporary storage of a 56 percent solution of ammonium nitrate containing a slight excess of ammonia. Again, the surface layers of the 2S sheet were found to contain detectable amounts of mercury.

Figure 6—Perforation of an aluminum alloy 2S tank handling 56 percent ammonium nitrate solution. Mercury was detected in this area. Approximate size of section photographed was 6 inches x 9 inches.

Figure 7—Selective attack that occurred on 85 out of 400 aluminum alloy 3S tubes (¾-inch dia.) in a wash oil cooler. The existence of mercury on the surface was established.

Wash Oil Intercooler

Another unusual corrosion problem was encountered with a 3S aluminum alloy tube bundle in a wash oil heat interchanger. In this service, the hot lean oil entered the shell and the cold rich oil entered the tubes. The unit had been in service three and one-half months when leaks suddenly developed. The bundle was pulled for examination and it was found that corrosion similar to that shown in Figure 7 had occurred on 85 out of 400 tubes in the bundle. In addition, the attack was confined to the tube surface between the tube sheet and the first baffle. A metallographic and chemical analysis of the tubes did not reveal any metallurgical differences in the tubes that might explain this behavior. Such a peculiar behavior is characteristic of corrosion caused by mercury or its compounds which was subsequently found by analysis.

Pipe Line for Carbon Dioxide

Another example showing the peculiar and characteristic behavior of mercury contamination occurred

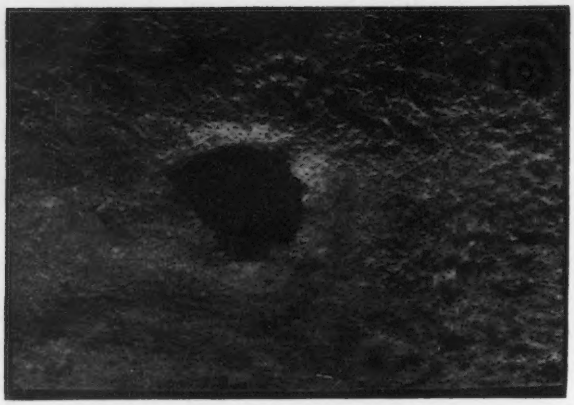

Figure 8—Section of an alumihum alloy 3S pipe handling gases largely composed of carbon dioxide. Mercury was present adjacent to the perforation. Approximate size of section photographed was 3¼-inches x 4¾-inches.

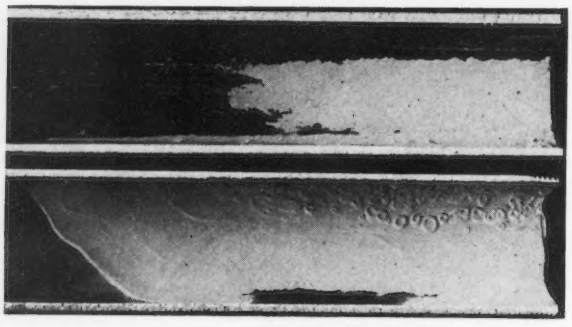

Figure 9—Attack typical of mercury contamination on aluminum alloy 63S pipe (2-inch IPS) handling steam condensate. The attack was confined to the light areas where globules of mercury were found (Figure 10).

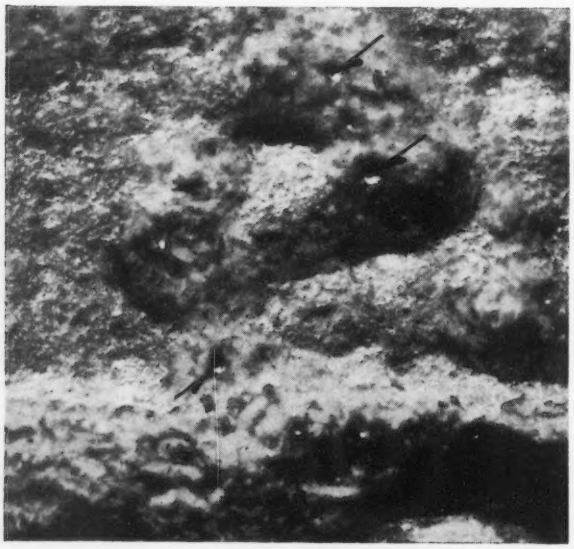

Figure 10—Corroded section of the pipe in Figure 9 showing the mercury globules (indicated by arrows) magnified 50 diameters.

in the production of carbon dioxide. In this case, a 3S aluminum alloy pipe line was used to carry the carbon dioxide gas. This line was inspected every four to six months and it was reported that the line was in excellent condition at each inspection. About one month after the 2½-year inspection, perforations (see Figure 8) developed in the line. Examination of the surface adjacent to the perforation revealed the presence of mercury.

Condensate Piping

Severe corrosion was encountered in a 63S aluminum alloy pipe line carrying condensate composed of water and a small amount of hydrocarbons. The peculiar attack on the pipe shown in Figure 9 was caused by mercury contamination. In fact, the contamination was so great that small globules of mercury could readily be seen (Figure 10) at a magnification of 50 diameters. Usually it is impossible to see mercury on the corroded samples except where a large amount of contamination occurs and the mercury must be detected by analytical methods. The amounts found by analyses on three different samples ranged from 4 to 15 micrograms per square inch. These concentrations detected on corroded samples were exceptionally high. Usually the amounts detected on such samples were on the order of 0.1 to 1 microgram per square inch of surface examined and sometimes even less.

Sources of Contamination

While it was concluded that the previous typical examples were corrosion problems caused by mercury contamination, in none of the cases did there appear to be any readily acceptable source of the contamination. In fact, in connection with several of the problems, it was flatly stated that there was no possibility of mercury in the system.

Some probable sources of such contamination were considered to be blown manometers, broken thermometers, or other mercury type instruments. In addition, many raw materials may contain sufficient amounts of mercury compounds to cause accelerated corrosion. In other cases, to further add to the confusion, it has been found that some refined chemicals have also been contaminated. It is most difficult to trace the source of contamination in many applications, particularly when it is remembered that the contamination need occur only once to cause severe corrosion.

The ease of contamination and the serious consequences were demonstrated by a series of laboratory investigations.

Laboratory Investigations

The literature contains many articles on the harmful effects of mercury or its compounds coming in contact with a number of metals and alloys. Many years ago[1, 2, 3] it was demonstrated that mercurous nitrate solution afforded a convenient method of detecting stresses in brasses and other copper alloys. The brasses reduce the mercurous ions to mercury which amalgamates with the brass more rapidly along grain boundaries than elsewhere. The liquid alloy produced weakens the grain boundaries and if the brass is under stress, cracking occurs along an intergranular path. Likewise, a stressed piece of brass or other copper-base alloy will fail when immersed in metallic mercury because of the preferential alloy-

ing along the grain boundaries. Metallic mercury amalgamates (alloys) readily with several nonferrous metals such as lead and tin,[4] but with more difficulty with aluminum alloys. The amalgamation either alters the electrode potential in localized areas, or prevents the formation of adherent films, or both, with the result that corrosion is promoted. Many metals can be amalgamated more readily with many mercury compounds than with metallic mercury. The mercury ions, because of their small size, can penetrate more readily through pores in the film and be reduced to metallic mercury. Adverse effects of mercury and its compounds on either corrosion or stress cracking have been reported in the case of metals and alloys, such as aluminum, brasses, bronzes, Monel, 17 percent chromium steel, 18 percent chromium-8 percent nickel steel, lead, tin, etc.[4, 5, 6] Consequently, it is not the purpose of this paper to belabor the fact that mercury and its compounds can cause difficulty, but rather to demonstrate some of the ways that mercury may be carried through a system or plant and to determine the order of magnitude of concentrations or amounts of mercury and its compounds that can cause difficulty.

Vaporization of Mercury

Although the vapor pressure of mercury is considerably less than that of many liquids, it is sufficient to permit some vaporization even at room temperature and as a result mercury vapor can be carried by a stream of fluid through a piece of equipment. Since mercury is not miscible with the liquids to be encountered, its vaporization can be considered as the distillation of two immiscible liquids. If the total pressure of the system is P, and the vapor pressure of the liquid in the system and that of the metallic mercury is p_x and p_{Hg}, respectively, mercury starts to pass through the equipment when

$$p_x + p_{Hg} = P$$

At temperature t, the ratio of atoms of mercury in the vapor (N_{Hg}) to the mols of the material in the vapor (N_x) is given by the relationship

$$\frac{N_{Hg}}{N_x} = \frac{p_{Hg}}{760 - p_{Hg}}$$

if the pressure within the equipment is 760 mm. Figure 11 shows this relationship for combinations of a variety of liquids immiscible with mercury plotted against the reciprocal equilibrium distillation temperature (°K) of two liquids, one being mercury. For example, this ratio at one atmosphere pressure for the distillation temperature of water and mercury is

$$\frac{N_{Hg}}{N_x} = 3.59 \times 10^{-4}$$

That is, for every mol of water vapor passing through the system, if equilibrium is attained, there will be 3.59×10^{-4} mols of mercury vapor accompanying the water vapor.

Vaporization of Mercury and Water

In order to demonstrate that the amount of mercury in the vapor from the distillation of water and mercury (although small compared to the amount of water vapor) is a significant and observable quantity, the apparatus shown in Figure 12 was used. Two hundred and fifty milliliters of distilled water and 2.2003 grams of mercury were placed in the flask and the water distilled at a rate of 60 ml per hour. After seven days 0.9735 grams of mercury had collected in the trap. In another test 250 ml of distilled water and 3.8420 grams of mercury were used. After seven days, 1.4240 grams of mercury had collected in the trap. It was observed that the mercury separated on

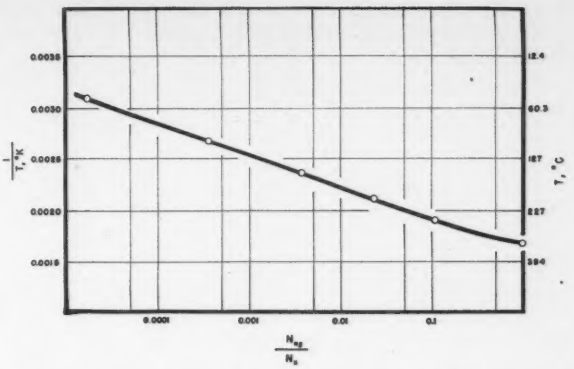

Figure 11—Ratio of the gram atoms of mercury (N_{Hg}) to the gram mols of component X(N_X) in the vapor at the equilibrium distillation temperature and at 760 mm pressure.

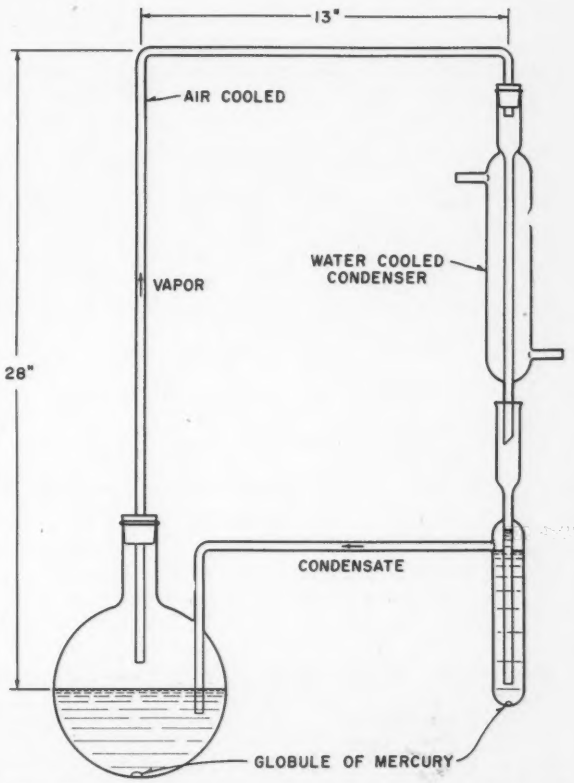

Figure 12—Apparatus for demonstrating the ease of vaporization of mercury. Water and mercury vaporized in flask and mercury accumulated in the trap at the right.

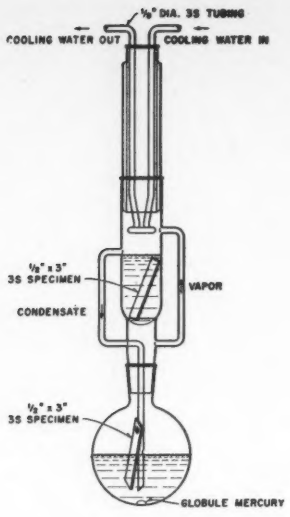

Figure 13—Apparatus for studying the corrosive effects of entrained mercury under boiling and condensing conditions.

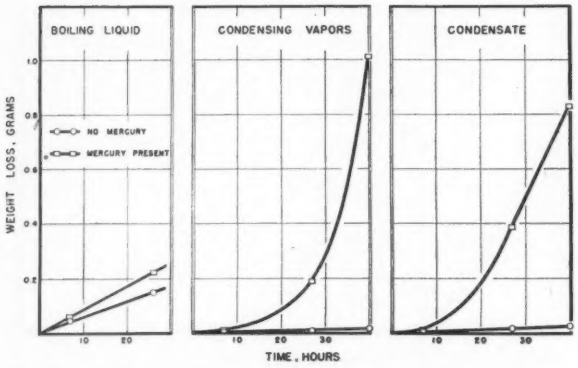

Figure 14—Effect of mercury contamination on the resistance of aluminum alloy 3S-H14 to corrosion by 0.5 molar acetic acid under boiling and condensing conditions.

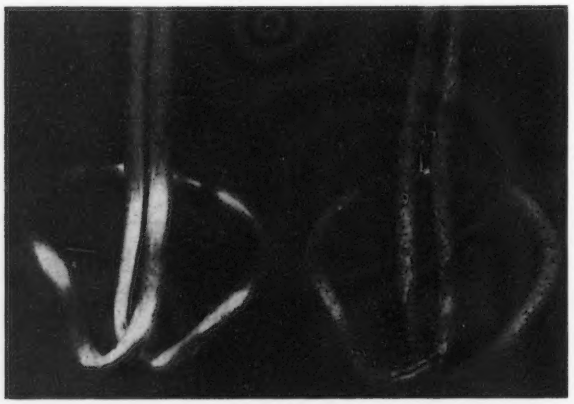

Figure 15—Appearance of the aluminum alloy 3S condenser tubes exposed to acetic acid vapors for forty hours. (Figure 14) The tube at the right was in contact with acid vapors containing mercury and was severely attacked and perforated. The other tube exposed to acid vapors without mercury remained in excellent condition.

the wall of the condenser tube as extremely small globules.

The results of the above experiments show that if metallic mercury is introduced into boiling aqueous solutions, the mercury can be easily transported throughout the system in vapor and condensate lines. Many of the small globules would coalesce to form larger globules which could collect in the bottoms of reaction vessels, storage tanks and pipe lines, or into any other cavities.

Corrosion Tests in Distillation Units

Since the above test demonstrated the ease with which mercury can be carried through vapor and condensate lines when aqueous solutions are boiled in contact with mercury, a test was devised to show how mercury carried in the vapor can accelerate corrosion. The glass apparatus shown in Figure 13 was used for these tests. A specimen of aluminum alloy 3S-H14 (0.064-inch x ½-inch x 3 inches) was partially immersed in 250 ml of boiling 0.5 molar acetic acid. The vapors passed up a side arm tube to the condenser made of a coil of ⅛-inch 3S aluminum alloy. Another specimen of aluminum alloy 3S-H14 (0.064-inch x ½-inch x 3 inches) was exposed in the condensate in the trap beneath the condenser. The results of tests run with and without a globule of mercury in the boiling liquid are shown graphically in Figure 14. The presence of mercury greatly accelerated the corrosion on the condensers and the specimens exposed in the condensate. In all the tests where a globule of mercury was present in the boiling liquid, small globules of mercury were observed on the condenser, and in the 40-hour test, the condenser

TABLE I

Corrosive Effects of Vaporization of Mercury in Ammonium Nitrate Solutions[1]

EXPOSURE	Weight Loss of Aluminum Alloy 3S-H14 After 21 Days Grams	
	No Mercury Present	Mercury Present[2]
Boiling Liquid[3]	0.1191	0.8310
Condensing Vapors[4]	0.1260	0.3437 Perforated
Condensate[3]	0.0054	0.0068

[1] Aqueous solutions 10 percent by weight.
[2] Globule of mercury in boiling liquid.
[3] Specimens 0.064 inches x ½ inch x 3 inches.
[4] ⅛ inch O.D. aluminum alloy 3S tubing.

TABLE II

Stress Cracking of Admiralty Erichsen Specimens in Condensing Vapors

SOLUTION[1]	Weight of Mercury Globule Grams[2]	Time of Failure Hours
Distilled Water	None	Did not fail (240 Hours)
Distilled Water	0.05	92
Distilled Water	0.05	195
Distilled Water	5	5
Distilled Water	5	17
0.5 Molar Hydrochloric Acid	None	Did not fail (240 Hours)
0.5 Molar Hydrochloric Acid	0.05	92
0.5 Molar Hydrochloric Acid	0.05	240
0.5 Molar Hydrochloric Acid	5	5
0.5 Molar Hydrochloric Acid	5	16

[1] 250 ml. of solution.
[2] Approximate weight of mercury globule in boiling liquid.

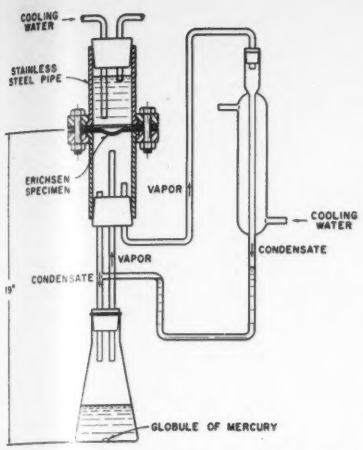

Figure 16—Apparatus for exposing Erichsen specimens to condensing vapors.

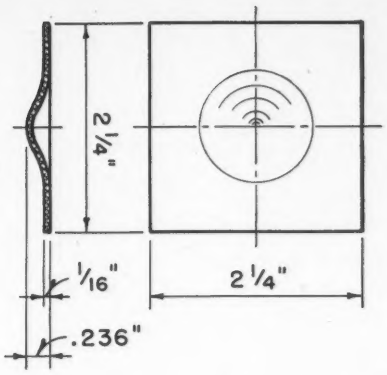

Figure 17—Erichsen type specimen used to study stress cracking.

was perforated as shown in Figure 15. Similar tests were run using a 10 percent (by wt.) ammonium nitrate solution and the condenser tube was perforated after 21 days when mercury was present in the boiling liquid. The specimen exposed in the boiling solution contaminated with mercury was also severely corroded. The results of the tests are given in Table I.

Stress Cracking of Admiralty Metal By Condensing Vapors

Stress cracking tests using Admiralty metal specimens were run in the apparatus shown in Figure 16. An Erichsen impression was placed in the sheet specimens as shown in Figure 17 in order to have residual stresses and plastic deformation in the specimen, as would be the case in a tube rolled into a tube sheet. A globule of mercury was placed in the flask along with 250 ml of distilled water or 0.5 molar hydrochloric acid and the solution boiled so that the vapors traveled 17.5 inches up through a glass tube and condensed on the water cooled Erichsen specimen held in the flanged assembly. The specimens were examined periodically for cracking. The results given in Table II on tests using distilled water and 0.5 molar hydrochloric acid show that cracking occurred in 5 to 17 hours when 5 grams of mercury were used and in 92 to 240 hours with 0.05 gram of mercury present. No cracking was observed in the tests with mercury-free solutions after 240 hours. A photograph of two of the cracked specimens is shown in Figure 18.

Pick-up of Mercury by Water

An experiment was carried out to determine the corrosive action caused by mercury pick-up in a solution. A liter of distilled water was refluxed in a glass flask for 72 hours with 16 grams of mercury. The solution was then decanted, filtered and analyzed for mercury. An analysis of the water revealed the presence of 0.05 ppm of mercury. Sodium chloride was then added to make a 0.5 molar solution. Specimens of aluminum alloy 3S-H14 (0.064-inch x ½-inch x 3 inches) were exposed for 30 days at room temperature to the above solution and also to a 0.5 molar sodium chloride solution made from distilled water refluxed without mercury. Although the weight losses in both types of solutions were not great (see Table III), they were consistently higher in the mercury-contaminated solutions. It is conceivable that if the contaminated solution was constantly changed, the mercury on the metal surface would eventually build up to a high enough level to cause severe corrosion.

Aluminum in Sulfuric Acid Solutions

Specimens of aluminum alloy 3S-H14 (0.064-inch x ½-inch x 3 inches) were exposed to 3.5 percent sulfuric acid plus 0.7 percent hydrogen peroxide at room temperature for four weeks, with a globule of mercury present in the flask. The specimens were suspended so that the bottom edges were ½-inch above the globule of mercury in the bottom of the flask. The data given in Table IV show that the corrosion was appreciably accelerated by the presence of metallic mercury in the solution.

Metallic Mercury Contacting Aluminum

The effect of various solutions in promoting amalgamation of aluminum was investigated by placing a globule of mercury in an open shallow impact extruded container (2-inch diameter x ½-inch deep x 0.020-inch wall) and then immersing the container in 500 ml of solution. The containers were exposed at room temperature to distilled water, 0.5 molar sodium chloride, 0.5 molar sodium chloride in synthetic Altoona water[7] and 0.5 molar acetic acid, both with and without mercury. The results given in Table V show that virtually no corrosion occurred in fourteen days in the distilled water and 0.5 molar sodium chloride solutions, even with mercury present. However, when mercury was present the cans exposed to 0.5 molar sodium chloride in the synthetic Altoona water and 0.5 molar acetic acid were severely corroded and perforated in less than 14 days' exposure. Tests were

TABLE III

Corrosion Behavior of Chloride Solution[1] Made with Water Contaminated with Mercury

TEST	Weight Loss of Aluminum Alloy 3S-H14[2] After 30 Days Grams		Difference Caused by Mercury Grams
	No Mercury Present[3]	Mercury Present[4]	
1	0.0012	0.0030	0.0018
2	0.0012	0.0030	0.0018
3	0.0012	0.0021	0.0009

[1] Solution 0.5 molar NaCl at room temperature.
[2] Specimens, 0.064-inch x ½-inch x 3-inch, exposed in 250 ml of solution.
[3] Solution made with distilled water that had been refluxed for 72 hours.
[4] Solution made with distilled water that had been refluxed for 72 hours in contact with mercury.

TABLE IV

Acceleration of Corrosion of Aluminum Alloy by Metallic Mercury in Sulfuric Acid[1]

TEST	Weight Loss of Aluminum Alloy 3S-H14[2] After 2 Weeks Grams		Difference Caused by Mercury Grams
	No Mercury Present	Mercury Present[3]	
1	0.2868	0.3715	0.0847
2	0.2876	1.1445	0.8569
3	0.2900	1.1477	0.8577

[1] Solution 3.5 percent by weight H_2SO_4 + 0.7 precent by weight H_2O_2.
[2] Specimens, 0.064-inch x ½-inch x 3-inch exposed to 250 ml of solution at room temperature.
[3] 1 to 1.2 gram mercury globule in bottom of beaker-specimen not touching globule.

TABLE V

Effect of Mercury Contacting Aluminum Alloy 3S-H14 in Various Solutions at Room Temperatures

Composition of Solutions[1]	Wt. of Mercury Grams	Time of Test	Wt. Loss[2] Grams	Appearance of Specimens
Distilled Water	0	14 days	0	Unaffected
Distilled Water	1.1456	14 days	0.0010	Slight etching around mercury globule.
0.5 Molar NaCl	0	14 days	0.0093	Slightly etched.
0.5 Molar NaCl	1.2262	14 days	0.0096	Slightly etched.
0.5 Molar NaCl[3]	0	14 days	0.0198	Etched.
0.5 Molar NaCl[3]	1.0512	14 days	0.0920	Perforated.
0.5 Molar NaCl[3]	1.1472	8 days	0.2533	Perforated.
0.5 Molar Acetic Acid	0	7 days	0.0117	Unaffected.
0.5 Molar Acetic Acid	1.1855	7 days	0.5786	Perforated.

[1] 500 ml of solution.
[2] The containers were 2-inch dia. x ½-inch deep x 0.20-inch wall thickness.
[3] In synthetic Altoona Water.

TABLE VI

Effect of Mercury on the Corrosion of Lead in Boiling Sulfuric Acid

Weight Loss[1] After 5 Days Exposure, Grams	
No Mercury Present	One Spot Amalgamated[2]
0.0150	0.0612
0.0134	0.0271

[1] Specimens 0.064-inch x ½-inch x 3-inches in 250 ml of 50 percent by by weight H_2SO_4.
[2] Amalgamated areas ⅜-inch in diameter.

TABLE VII

Acceleration of Corrosion of Aluminum Alloy by Solutions Containing Slightly Soluble Mercury Compounds

Mercury Compound	Weight Loss of Aluminum Alloy 3S-H14 After 2 Weeks—Grams[1]	
	Position of Specimen in Flask	
	Suspended in Solution Above Compound	Lower ½" of Specimen Buried in Compound
SOLUTION OF 0.5 MOLAR SODIUM CHLORIDE		
None	0.0012	.....
None	0.0012	.....
Hg_2Cl_2	0.0008	0.1520
Hg_2Cl_2	0.0841	0.1967
HgO	0.1520	0.2225
HgO	0.1967	0.2575
SOLUTION OF 0.5 MOLAR SODIUM SULFATE		
None	0.0018	.....
None	0.0014	.....
$HgSO_4$	0.0257	0.2057
$HgSO_4$	0.0589	0.0215

[1] Specimens 0.064-inch x ½-inch x 3-inch exposed in 250 ml volumes of solution at room temperature.

also run in which the solutions were stirred, but the results were inconsistent in that amalgamation was accelerated in some cases and not in others. The above results demonstrate that amalgamation with metallic mercury is not consistently produced and is aided by a slightly corrosive environment.

Lead in Boiling 50 Percent Sulfuric Acid Solution

Lead specimens (0.064-inch x ½-inch x 3 inches) were exposed to 250 ml of boiling 50 percent sulfuric acid for five days. A spot about ⅜-inch in diameter was amalgamated on two of the specimens and the other two were exposed free from mercury. The results given in Table VI show that the corrosion was definitely higher with mercury present than without.

Sparingly Soluble Mercury Compounds

Normally mercurous chloride, mercuric oxide and mercurous sulfate are considered for all practical purposes to be virtually insoluble in aqueous solutions. To demonstrate that these compounds dissolve to a sufficient extent to accelerate corrosion, large excesses of mercurous chloride and mercurous sulfate were placed in 250 ml volumes of 0.5 molar sodium chloride and sodium sulfate, respectively. In addition, mercuric oxide was also investigated in the sodium chloride solution. Specimens of aluminum alloy 3S-H14 (0.064-inch x ½-inch x 3 inches) were exposed for two weeks at room temperature in such a manner that one specimen was partially embedded in the mercury compound paste on the bottom of the beaker and the other specimen suspended in the aqueous solution, but not contacting the paste. The data presented in Table VII show that the corrosion was markedly accelerated on all specimens. In all but one case this was especially true on the portions of the specimens buried in the mercury compound paste. The excessive corrosion on the buried portions of the specimens was the result of the shorter diffusion paths for the mercury ions, which would allow the mercury ions in the solution adjacent to the buried portion to be replenished at a much faster rate than possible in the main body of the solution.

Soluble Mercury Compounds

Minimum concentration levels of mercury contamination that would accelerate corrosion were investigated in a solution of 3½ percent (by wt.) sulfuric acid containing 0-50 ppm of mercury as mercurous sulfate and in 0.5 molar sodium chloride solution containing 0-5 ppm mercury as mercuric chloride.

The specimens (0.064-inch x 2-inches x 4 inches) were waxed on the edges and one face, leaving only one surface exposed. The purpose in following this procedure was prompted by the previous investigations which indicated, as would be expected, that the mercury attacked cut edges more readily than the flat surfaces.

The specimens were exposed for ten days at room temperature with and without daily solution changes. In the case of the sulfuric acid, it was found that when the solutions were not changed daily (see Figure 19) no significant change in the rate of attack

occurred until a concentration level of 2.5 ppm of mercury was exceeded. However, when the solutions were changed daily the concentration level above which corrosion was accelerated was lowered from 2.5 ppm to about 0.5 ppm. As can be seen in Figure 19, the severity of attack was greater when a solution containing 5 ppm was changed daily than when one containing 50 ppm was not changed.

The results of a similar test conducted in 0.5 molar sodium chloride are shown graphically in Figure 20. In general, the same behavior was observed. However, in this case, it appeared that the concentration levels above which corrosion was accelerated were lower than in the sulfuric acid solutions, although the rates of attack were not great. Thus, it is apparent that in a particular application the mercury concentration level may be extremely low, but over a period of time severe corrosion may occur.

Cupro-Nickel and 304 Stainless Steel In Sodium Chloride Solutions

Cupro-nickel and 304 stainless steel specimens (0.064-inch x 2¼-inches x 2¼ inches) were exposed to 500 ml of 0.5 molar sodium chloride with various amounts of mercury, added as mercuric chloride, for 28 days at room temperature. The results of the tests are shown graphically in Figure 21. The corrosion was accelerated with both alloys at a mercury concentration level of only 0.5 ppm and the corrosion increased steadily as the mercury concentration was increased. It was observed that the turbidity of the solutions in which stainless steel specimens were exposed increased with increasing concentrations. For example, turbidity measurements showed that the turbidity of the solution containing 1 ppm of mercury was about 3.5 times higher than the blank at the end of the test. No cracking of Erichsen specimens of these alloys in these solutions was observed, although it was reported in the literature that mercurous chloride solutions cause cracking of stressed stainless steels of the 304 type.

Stress Cracking Experiments

No data were readily available on the lower concentration levels of mercury compounds which will cause stress cracking on various metals. For this reason stress cracking experiments were run by exposing Erichsen specimens to 0.5 molar sodium chloride and New Kensington tap water[7] with various concentrations of mercury added as mercuric chloride. Erichsen specimens of aluminum alloys 3S-H14 and 61S-T6, Admiralty metal, cupro-nickel, Monel, 304 stainless steel and zinc were tested. The specimens were exposed in duplicate for four weeks at room temperature to solutions containing 0, 0.01, 0.1, 0.5, 1, 10 and 100 ppm of mercury and examined periodically for cracks at a magnification of 15 diameters.

With the exception of the Admiralty metal and Monel specimens, no cracking was observed with any of the alloys under these particular test conditions. In the case of the Monel specimens exposed in 0.5 molar sodium chloride containing 100 ppm of mercury, both specimens cracked in 92 hours and in the solution containing 10 ppm mercury, one specimen cracked in 137 hours. No cracking occurred in four weeks in any of the other solutions, including the New Kensington tap water test.

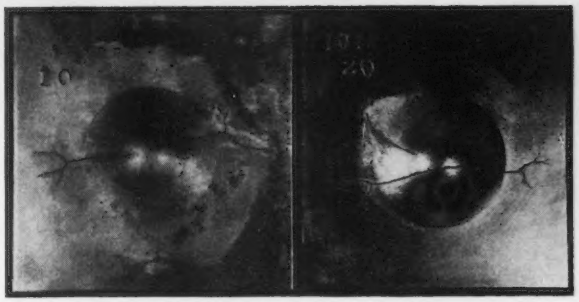

Figure 18—Stress cracking developed in Admiralty metal Erichsen specimens exposed to condensing vapors containing traces of mercury.

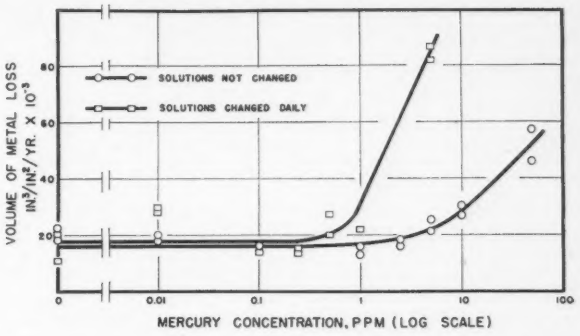

Figure 19—Resistance of aluminum alloy 3S-H14 to corrosion by 3½ percent sulfuric acid containing low concentrations of mercurous sulfate at room temperature. The specimens were exposed for ten days.

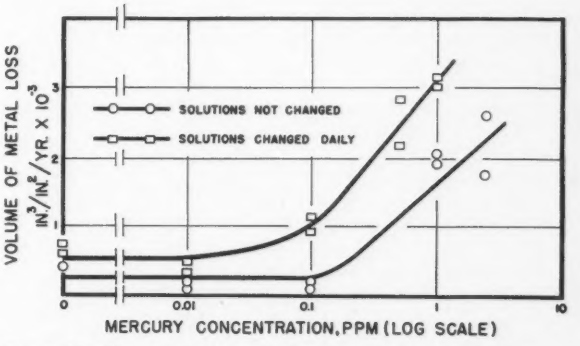

Figure 20—The acceleration of corrosion at room temperature of aluminum alloy 3S-H14 caused by the presence of low concentrations of mercuric chloride in 0.5 molar sodium chloride. The specimens were exposed for ten days.

Admiralty metal was found to be susceptible to stress cracking with the mercury concentration level as low as 0.25 ppm in the sodium chloride solution and 5 ppm in New Kensington tap water. The results of this investigation are shown in Figure 22. As can be seen, the time to crack increased as the mercury concentration level was lowered. A photograph representative of the cracking that occurred on the Admiralty metal is shown in Figure 23.

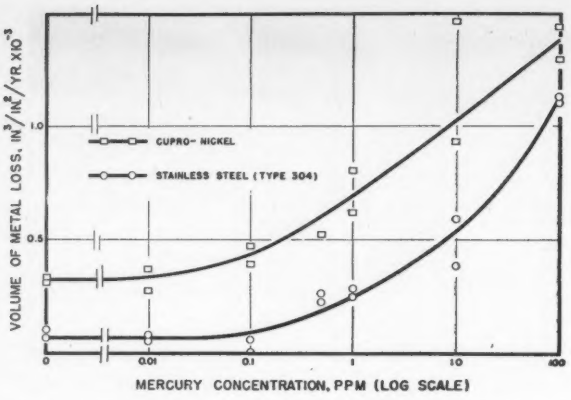

Figure 21—Corrosion of cupro-nickel and stainless steel type 304 in 0.5 molar sodium chloride containing low concentrations of mercuric chloride at room temperature. The specimens were exposed for 28 days.

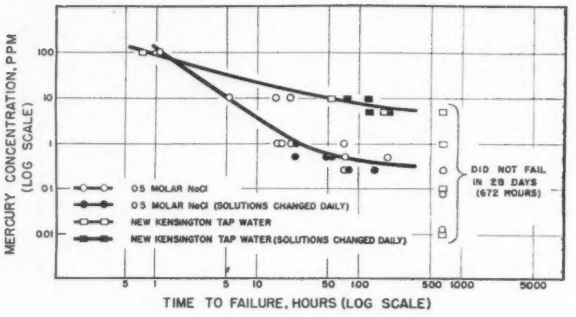

Figure 22—Mercury concentrations causing stress cracking of Admiralty metal Erichsen specimens in 0.5 molar sodium chloride and New Kensington tap water at room temperature.

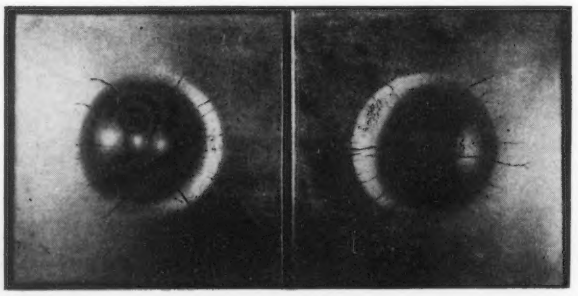

Figure 23—Stress cracking resulting from exposure of Admiralty metal Erichsen specimens to 0.5 molar sodium chloride containing 1 ppm of mercury at room temperature.

TABLE VIII

Relation of Mercury Detected on Corroded Specimens to the Mercury Concentrations of the Solutions

Concentration of Mercury in Solution ppm	Total Amount of Mercury Present in Solution[1] Micrograms	Mercury Detected on 5 Square Inches[2] Micrograms
100	50,000	90
50	25,000	40
25	12,500	20,10
10	5,000	50,20
5	2,500	20,15

[1] 500 ml. of 3½ percent by weight sulfuric acid.
[2] Specimens (0.064-inch x 2-inch x 4-inch) of aluminum alloy 3S-H14 with edges and one side waxed, exposed for 10 days at room temperature.

It was found that small galvanic currents aided in the reduction of the mercury compounds in solution. To illustrate this point, Erichsen specimens of Admiralty metal coupled to zinc specimens were exposed to 0.5 molar sodium chloride solutions containing mercury as mercuric chloride. Under these conditions cracking of Admiralty metal was observed in solutions containing only 0.1 ppm of mercury.

Thus it can be seen that in many applications where stress cracking is encountered, the source of the trouble may well be attributed to traces of mercury or mercury compounds.

Detection of Mercury on Corroded Specimens

In corrosion problems involving mercury contamination, the relation between the original mercury concentration in solution and the amounts detected on the surface of exposed specimens is very important. This relation was investigated by exposing specimens of aluminum alloy 3S-H14 (0.064-inch x 2 inches x 4 inches), waxed on the edges and one side, to 3½ percent (by wt.) sulfuric acid containing various concentrations of mercury as mercurous sulfate. After ten days' exposure at room temperature the specimens were removed for analysis. The results given in Table VIII show that the amounts of mercury detected were not consistent and could not be correlated with the initial mercury concentrations in solution. It was very interesting to note that while the amount of mercury detected in each case was only a small and inconsistent fraction of the total quantity of mercury available, the rate of attack in these solutions, as was shown in Figure 19, increased with increasing mercury concentration in the solution.

Conclusions

The results of laboratory work and service experience have demonstrated that mercury contamination, either metallic or its compounds, constitutes a serious corrosion menace. It is believed that control of mercury contamination could easily be justified by the savings that would result from less replacement and maintenance of chemical process equipment.

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The Pitting of Zinc By Distilled Water and Dilute Solutions ★

By U. R. EVANS and D. E. DAVIES*

Abstract

The object of the research was to explain the vertical arrangement of pits produced on zinc by distilled water, to study the corrosion products and to explain their formation. The vertical alignment is due to corrosion product from an upper pit lodging at points below and screening them from oxygen; lines of pits can also be set up by the screening action of a polythene thread. A zinc disc whirled in distilled water containing oxygen suffers no pitting. In stagnant water containing oxygen under high pressure, zinc remains unchanged; at ordinary pressure, it becomes pitted. The pits contain white matter and are surrounded by white rings (oriented zinc oxide and some β-hydroxide); further from the pits are films of interference-color thickness (also oriented zinc oxide), whilst negatively charged colloid particles appear in the liquid. Salt solutions produce a distribution of attack different from that given by distilled water. The results are explained on the theory of oxidation and corrosion advanced by Hoar and Evans.

THE ATTACK produced by distilled water on zinc is slow, even in presence of oxygen; it is, however, localized as pits, and may cause perforation of thin sheet. Bengough and O. F. Hudson[1] noticed that on cast zinc placed in stagnant distilled water, the pits appeared in straight vertical lines. The arrangement was evidently connected with gravity; a disc of zinc immersed in distilled water contained in a slowly rotating beaker developed a pattern of pits recalling a Catherine wheel; centrifugal force here played the part of gravity.

Evans[2, 3, 4] obtained the same vertical arrangement of pits on rolled zinc. The distribution in distilled water was different from that obtained in sodium or potassium chloride solution. Drops of salt solution placed on a horizontal surface produced attack at their centers, with a broad unattacked zone around the periphery; a ring of zinc hydroxide was formed between the two zones. The results were explained on the basis of differential aeration. The alkali formed at the peripheral (cathodic) zone caused the liquid to spread, so that the area of the drops increased. Drops of distilled water produced attack close to their edges; the white corrosion product formed a crinkled ring which actually touched the periphery at some points, but at others was separated from it by a narrow area free from attack; the main attack occurred just within or below the white ring and, since no alkali was formed, there was no spreading. The presence of carbon dioxide was not needed for attack; water obtained by distillation of dilute sodium hydroxide solution and condensed directly as droplets on the zinc surface caused appreciable corrosion. If much carbon dioxide was present, the attack was considerable, but there was no white corrosion product. The effect of carbon dioxide on the action of distilled and natural water on zinc has been studied in detail by Kenworthy and Smith.[5]

E. A. Anderson and Fuller[6] found anhydrous oxide on zinc subjected to distilled water free from carbon dioxide, but basic carbonate where the water had contained carbon dioxide. Gibert[7] reported hydroxide when London tap water acted on zinc. Feitknecht and Petermann[8] studying the attack of zinc chloride solution on zinc, found considerable hydroxide (α-, β-, and ε-forms). In distilled water the inner film was oxide, and the outgrowth β-hydroxide. Feitknecht[9] states that he would expect primary zinc oxide round the pits, and that the loose material covering the pits, although originally amorphous or α-hydroxide, might later change into oxide or β-hydroxide.

Not only is the distribution different for distilled water and salt solution, but also the kinetics. Bengough, Stuart, and Lee[10, 11, 12] showed that fairly concentrated potassium chloride solution attacks totally immersed zinc in presence of oxygen, according to a rectilinear law, the oxygen-uptake V, in time t, being given by $dV/dt = k_1$, whereas the attack by distilled water or very dilute postassium chloride solution was asymptotic, the relation being $dV/dt = k_2(V\infty - V)$ where $V\infty$ is the limiting value of V and k_1, k_2 are constants. The rectilinear relation was found to be valid for alloys by Borgmann and Evans[13] who used cylindrical rods of zinc or alloy cast in glass. When corrosion was plotted against time, the points fell on straight lines, but the gradient varied. Thus spectroscopically pure zinc was attacked somewhat more slowly than "ordinary" zinc, whereas each alloy corroded at a different rate; iron and, still more so, copper increased the attack on "ordinary" zinc, whereas aluminum diminished it.

Bengough, Stuart, and Lee[10, 11, 12] noticed that in distilled water and N/10,000-potassium carbonate the curves showed sudden breaks; after the corrosion rate had become negligibly slow, the attack suddenly started again, as though a protective film had disintegrated, and then gradually attack died down. Many such breaks on corrosion-time curves have been reported—for instance during the high-temperature oxidation of copper (Pilling and Bedworth,[14]) and during the atmospheric attack on aluminum exposed to London air.[15]

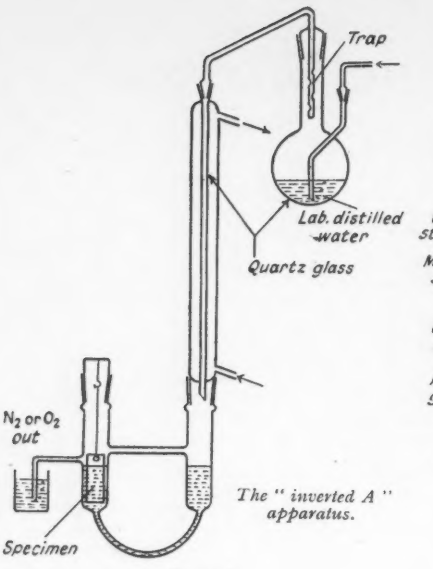
The present paper describes an investigation into the causes of the localized attack, the vertical arrangement of pits, and the character of the corrosion products.

Experimental

Zinc.—Two grades of zinc sheet (Zn/49, Zn/50) were kindly provided by the British Non-Ferrous Metals Research Association, and slabs of spectroscopically pure zinc by the New Jersey Zinc Company. The compositions are shown in the Table.

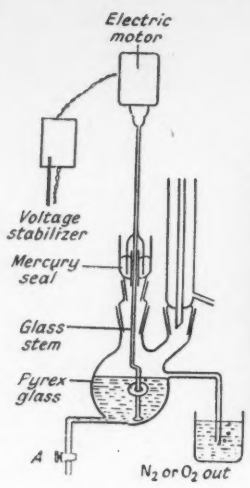
★ Preprinted from the Journal of the Chemical Society (U.K.) 1951. EDITOR'S NOTE: This paper is being preprinted in CORROSION because it shows how valuable information can be obtained by simple experimental techniques.

* Both with Department of Metallurgy, University of Cambridge, Cambridge, England.



The "inverted A" apparatus.

Figure 1



(Not to scale.)

Figure 2

Figure 3

	Zn/49.	Zn/50.
Thickness	0·50 mm.	0·48 mm.
Iron, %	0·002—0·003	0·002
Lead, %	0·012—0·016	Trace (<0·002)
Copper, %	0·001	Trace (<0·001)
Cadmium, % ..	0·002	Trace (<0·002)
Magnesium, % .	Not detected	Trace (<0·001)
Tin, %	Not detected	Not detected
Aluminum, % .	Not detected	Not detected

Many of the experiments were carried out on the "as-rolled" surface, after degreasing; the specimens were alternately immersed in acetone and withdrawn, the liquid film being sucked off with blotting paper before it could evaporate; they then received vapor-degreasing in benzine. In other cases the surfaces were abraded, after degreasing, by use in turn of Oakey's G,F,M,O, 2/0, 3/0 and 4/0, which leaves a very smooth surface; a further degreasing followed.

Both Zn/49 and Zn/50 gave practically the same types and distribution of pitting, and these were the same on a finely abraded as on an "as-rolled" surface. Commercial zinc sheet ("as-rolled" condition) gave somewhat similar pitting. The spectroscopically pure zinc, being rough, could only be used after abrasion, which may have introduced impurities; the same results were obtained.

Apparatus.—The distilled water used for the principal experiments was prepared in the laboratory by the further purification of "ordinary" distilled water, previously condensed in glass in a small laboratory still. Subsidiary experiments were carried out with samples of high-quality distilled water kindly provided by other laboratories. All samples gave similar results; the pitting produced by the purest water was more clear cut, the pits being deeper but less numerous than those produced by less pure samples.

In view of Kenworthy's demonstration of the effect of traces of copper salts on the corrosion of other materials,[16] metals were avoided in designing the still; the redistillation was carried out in an all-quartz apparatus, supplied by the Thermal Syndicate (Figure 1), the design of the trap being due to Dr. A. E. J. Vickers, who kindly tested the carry-over. It was possible to pass nitrogen (purified by passage through 30 percent potassium hydroxide solution) through the boiling water, so as to wash out carbon dioxide, before condensation of the steam was started. It was also possible to attach, directly to the outlet, an "inverted A apparatus," which allowed the pH value to be obtained by means of a glass electrode, or alternatively allowed the action on zinc to be studied, without access of air. In general, the vessel was kept full of nitrogen while the inverted A apparatus was filling with water. No visible attack on the zinc occurred until oxygen was admitted.

The quartz-condensed water, if allowed exposure to the air, took up a pH of 5·3—5·5; this is close to the value of 5·7 calculated for water standing in equilibrium with the amount of carbon dioxide commonly present in the atmosphere. When, by the nitrogen method, the carbon dioxide present in original distilled water was eliminated, a pH value as high as 8 was obtained, suggesting presence of a trace of ammonia. The conductivity varied between 0·07 and $0·2 \times 10^{-6}$ mho cm.$^{-1}$.

Another method of obtaining pure water was to pass "ordinary" laboratory distilled water down a column of mixed resin "Bio-deminrolite F" which replaces the common anions by $(OH)'$ and the common cations by $H^{\bullet}$ (Akeroyd and Kressman[17]; this gave a water of conductivity $0:2 \times 10^{-6}$ mho cm.$^{-1}$ and pH 6·4—6·5. It is not clear how the pH numbers compare with those of samples prepared elsewhere, since most investigators have not quoted pH, but only conductivity.

When it was desired to whirl a disc of zinc under controlled conditions, the apparatus of Figure 2 was employed (based on that of Evans, "Corrosion of Metals.")[18] The disc has a central hole large enough to fit loosely over the glass stem and when there is no rotation rests on the broad foot. During rotation it mounts up the stem, being in contact with glass at only one point at any moment; this point of contact is constantly changing, and there can be no screening from dissolved oxygen.

Results

Vertical Alignment of Pits.—Experiments on partly immersed vertical sheet specimens confirmed the arrangement of pits in vertical lines—somewhat "wavy" unless convection currents were eliminated (Figure 3). The pits were filled with white corrosion product and were generally surrounded by rings of the white product; the rings around adjacent pits sometimes merged into loops. Outside the white rings, the zinc was unattacked but showed interference colors when viewed by specular reflection; the arrangement of the colors showed the film to be thickest nearest to the pits; contour traces obtained with

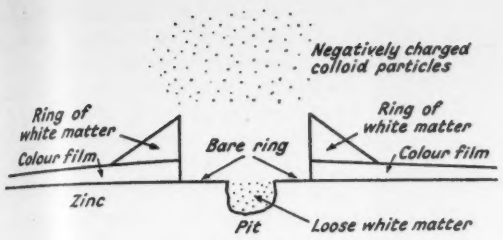


Figure 4

a Talysurf apparatus appear to confirm this. When the rings of white matter were brushed off, the interference-color film was found to continue below them (Figure 4). X-ray studies showed the white product scraped from around the pits to be zinc oxide with some β-zinc hydroxide (identified by a table of spacings kindly provided by Prof. Feitknecht). The white matter obtained from within the pits gave no lines—suggesting that it was amorphous, although the quantity was too small for confident decision. Electron-diffraction studies showed the material responsible for the interference colors to be the anhydrous oxide, with preferred orientation; the white rings also showed orientation. The original "as-rolled" surface was found to carry an anhydrous oxide film without preferred orientation, much thinner than the color film, as judged from the feebleness of the rings.

After the experiment, the water contained colloidal particles, presumably zinc hydroxide, and gave a good Tyndall cone. Electrophoresis experiments showed that they carried a negative charge.

In somewhat exceptional cases, the pits were found to follow marks left by the rolling, but in general they were independent of surface blemishes. The arrangement of pits along vertical lines was obtained on "as-rolled" or abraded specimens placed with the rolling or abrasion direction at 45° to the vertical. On hand-polished specimens, the pits were likewise arrayed vertically above one another; transverse abrasion lines made just before immersion remained free from pits. Evidently something dropping from the uppermost pits sets up pitting at points vertically below one another.

When zinc specimens were partly immersed in distilled water in a sloping position, the usual straight lines of pits and loops were obtained on the upper portion, where white matter produced by a pit situated at a high point could slide down the metallic surface until it lodged at some lower point, there producing a fresh pit. On the lower side, where solid matter breaking off from the surface must fall clear of the zinc, the tendency to the linear arrangement of pits was not observed.

The distribution of attack was affected by impurities in the gas phase. Air purified by sodium hydroxide solution gave pits similar in some cases to those obtained with oxygen; if the purification was omitted, the corrosion extended over vertical streaks bounded by loops of solid white matter. There was then no pitting. This corrosion was probably due to the formation of appreciably soluble zinc hydrogen carbonate, and the phenomenon is probably analogous to the arch-shaped area of corrosion commonly noticed in the early stages when iron or zinc is immersed vertically in sodium or potassium chloride (Evans[19], Borgmann and Evans[20]). Along the edges of the arches are walls of membranous iron or zinc hydroxide formed by interaction between the iron or zinc chloride from within and the alkali formed outside.

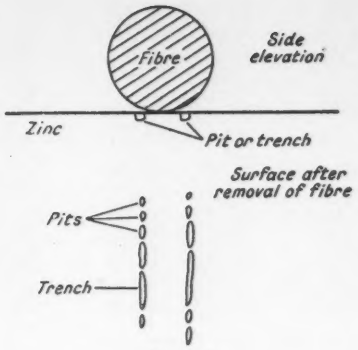


Figure 5

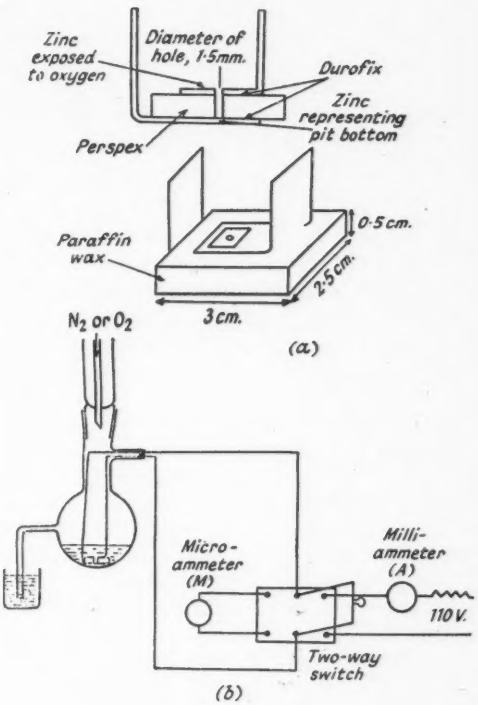
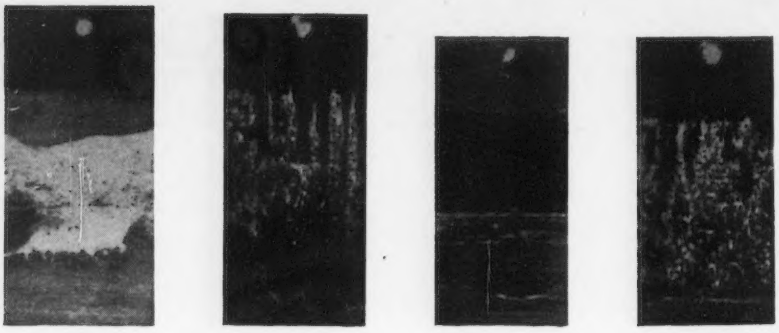


Figure 6

Production of Pits by Contact with Other Materials.—If the white corrosion product from one pit can set up pitting at a point which otherwise would be immune, other substances might be expected to produce the same effect. Experiments were carried out on totally immersed horizontal specimens around which fibres had been tied or pressed. The fibres used included Polythene (drawn out in the laboratory to a fine thread), glass (similarly drawn out), and linen thread. The elastic character of the Polythene threads allowed them to be brought uniformly into contact with the metal surface over their whole length; thus they set up intense localized corrosion consisting of two parallel trenches or pit-lines, doubtless cor-



M-KCl M/100-KCl M/75-KCl M/500-KCl

Figure 7

responding to the two crevices on each side of the line of contact (Figure 5). The linen thread gave less pronounced trenching, whilst glass gave none. The materials may produce specific effects, but the effectiveness of Polythene is probably due to the formation of suitably shaped crevices.

The most reasonable explanation of the intense corrosion at crevices (whether set up by corrosion product or by Polythene) is that the metal, being locally shielded from oxygen, becomes anodic to the main surface. The combination of small anode and large cathode leads, as usual, to intense attack.

Demonstration of the Corrosion Cell.—Since the idea of corrosion currents in liquids of poor conductivity is unfamiliar, it seemed well to study a "model cell" representing the situation at a pit. Helpful discussion with R. May, who has much experience of "model cells," led to the form shown in Figure 6*a*; the liquid was distilled water. To break down the oxide already present on the lower zinc and thus start anodic attack, an electric current from an external battery was first passed under a current of nitrogen from the lower zinc sheet as anode to the upper zinc as cathode. When this external current was cut off by shifting the double-pole switch from the right-hand position to the left (Figure 6*b*), the current started to flow back through *M*, with the lower zinc as cathode; this merely represented the usual behavior of a polarized system, being analogous to the discharge of an accumulator. The back-flow current dropped to zero in about three hours and in experiments under nitrogen no current was produced in the opposite direction. If, however, the nitrogen was replaced by oxygen soon after the polarizing current had ceased to flow, then a current in the forward direction was obtained, the bottom zinc acting as anode and the upper (aerated) zinc as cathode. The current became constant after a few hours at a value varying in different experiments from 0·5 to 1·5 microamperes. The experiments suggest that a corrosion current can continue to flow through distilled water under geometrical conditions similar to those existing during the pitting of zinc.

Experiments with Eccentric Whirler.—If the pitting or trenching set up by contact with zinc oxide particles (or with Polythene thread) is really due to local screening from oxygen, it would seem possible to prevent intense attack by maintaining an oxygen supply at all points on the surface, with the eccentric whirler (Figure 2). A zinc disc whirled in distilled water with oxygen above the water surface remained free from pitting or any visible change; under stagnant conditions, experiments, carried out in the same apparatus containing the same water and the same oxygen, produced pitting, whether the zinc was totally or partly immersed. A small and rather variable concentration of zinc was detected in the water under whirling conditions, but this showed no tendency to increase beyond about 10^{-5} g.-ion/l.; the estimation was carried out in a Spekker apparatus by a method due to Mayne and Noordhof[21] based on sodium diethyldithiocarbamate. The loss of weight of the zinc at the end of 4 days was about 0.0008 g.—similar to that found in the water after whirling, namely 0.00065 g.

Experiments under Pressure.—Even under stagnant conditions, oxygen under pressure (10 atmospheres, decreasing to 7 atmospheres during the experiment) prevented pitting. This was shown by experiments in glass vessels enclosed in a stainless steel "bomb." Bengough and Wormwell's method[22] was used, the high-pressure oxygen being introduced before the water; when the water was introduced before the pressure was raised, pitting occurred.

Experiments in Chloride Solutions of Different Concentrations.—Zinc was tested in potassium chloride solutions of concentrations 2·0, 1·0, 0·2, 0·1, 0·02, 0·01, 0·002, 0·001, 0·0002, 0·0001, 0·00002 and 0·00001 M. In one series, plates were partly immersed in the solutions; in another, drops of solution were placed on horizontal plates. Well below 0·01 M., the distribution somewhat recalled that produced by distilled water, with numerous pits surrounded by loops; at many points the corrosion product reached the water-line (in partial immersion experiments) or the drop margin (in drop experiments). Well above 0·01 M., there was a continuous unattacked area below the water-line or around the drop periphery; this area showed high-order interference tints, indicating a film thickest near the water-line; electron diffraction identified the film as oriented zinc oxide. Round about 0·01 M., both types of attack were found at different places. The situation is shown in Figure 7. Sodium chloride and potassium sulphate gave similar results.

Discussion

Facts requiring Interpretation.—Any satisfactory mechanism must explain: 1) absence of attack when oxygen is absent; 2) pitting under stagnant conditions when oxygen is present; 3) absence of pitting under whirling conditions even though oxygen is present; 4) preferential pitting where particles of corrosion product settle or at contact with thread; 5) loose oxide and ε-hydroxide in pits; 6) negatively charged colloidal particles in liquid; 7) color film of oriented zinc oxide thickening towards pits; and 8) white zinc oxide also oriented overlying color film in its thickest region.

Effect of Oxygen Distribution.—The whirling ex-

periments suggest that, to maintain a protective film on zinc, oxygen must be replenished as soon as it has been used up in repairing "weak points" of the film. When whirling stops, corrosion starts at certain points, although the oxygen concentration must at the moment of stoppage be uniform and equal to the saturation value. The weak points may be places where the film is rich in defects owing to the presence of impurities or broken by internal stresses; if the film has cracked at a point, it will during the repair process remain thinner there than elsewhere. The term "weak point" will include other places where the outward movement of zinc ions through the film is abnormally easy; for instance, places where the metal is disarrayed and thus energy-rich, providing a more rapid stream of cations through the film than occurs elsewhere.

Evidently there are grades of weakness. A very weak point will require a very rapid replenishment of oxygen for its effective repair. A moderately weak point may be repaired easily under the ordinary rate of replenishment characteristic of "unstirred" water, but not if that part of the surface is screened from oxygen by means of a Polythene thread. But shielding from oxygen, however complete, will not of necessity produce corrosion. All that it does it to increase the probability of corrosion; within a shielded region, there will in general be both pits and uncorroded zinc, although the shielding is, at the outset, no greater at the points which develop pits than elsewhere. The fact that the probability of attack increases as oxygen supply diminishes was shown for iron in distilled water by Mears and Evans.[23]

If the pitting and trenching below a Polythene thread is attributable to oxygen-shielding, it is easy to explain the arrangement of pits on different surfaces. On a vertical surface, the corrosion product formed at a pit near the top will fall by gravity; if particles lodge at points on the surface, they will diminish the possible replenishment rate for oxygen so that minor weak points—which would not develop pitting on an unshielded surface—will become the sites of pits; hence the arangement in vertical lines. This cannot happen on a horizontal surface; hence the original pits will not give birth to others. Nor can it happen on the lower side of a sloping plate; on the upper side particles can slide downwards and the lines of pits are again obtained.

Electrochemical Action Around a Weak Point.—Imagine a horizontal zinc surface carrying an oxide film and placed in water containing dissolved oxygen; imagine that the main part of the film is sound but that one weak point exists, through which zinc cations can move outwards (also electrons, since the defects which permit movement of ions usually favor movement of electrons). If the rate of replenishment of oxygen in the liquid is good, there will always be a layer of absorbed oxygen *atoms* on the outer surface, which can be converted into *ions* by the electrons moving outwards; consequently the zinc cations as they arrive at the outer surface can take up their places between the oxygen anions, giving an extra layer of zinc oxide. Thus, the film locally thickens, by accretion on the outside—a mechanism precisely similar to that demonstrated by Wagner[24] for the formation of oxide-films on *dry* metal; the thickening at the weak spot continues until the increased thickness reduces the rate of movement of cations outwards, in other words until the spot has ceased to be exceptionally weak; pitting is avoided.

If the liquid contains no oxygen, the emerging cations can enter the liquid, becoming hydrated. However, this would soon leave the metal negatively charged, and the escape of cations must then cease (except insofar as the charge can be balanced by the deposition of hydrogen ions at points around, which can probably be neglected owing to the high over-potential of zinc). Again, there is no pitting.

If the maximum rate at which oxygen can be replenished is insufficient to arrest the zinc ions as they emerge, but is sufficient to provide adsorbed oxygen atoms at the area of sound film surrounding, and *very* close to, the weak spot, then the excess of electrons left behind when the cations enter the liquid may serve for the reduction of the oxygen. In other words, electrochemical reactions are set up which may tentatively be written thus:

at the weak spot (anodic)	$Zn = Zn^{++} + 2e$
on the sound film (cathodic)	$O_2 + 2H^- + 2e = H_2O_2$

Since the number of cations produced is equal to the number destroyed, there are no unbalanced ions. The hydrogen peroxide could be reduced to water by further cathodic action, but since hydrozen peroxide has been detected in fairly large amounts in the action of distilled water on zinc or other metals (Traube,[25] Churchill,[26] Delahay,[27] the second step does not seem to be complete.

Once zinc cations have accumulated in the liquid and reached the cathodic area, a different cathodic reaction becomes possible. The adsorbed oxygen atoms are converted into ions by the electrons, and the zinc cations arriving from the anode take their places between them, giving fresh layers of zinc oxide, as identified by electron diffraction. This formation of zinc oxide differs from the ordinary oxidation in air in that cations arrive *from the outside*. Thus, provided that electrons can move easily through the film, there is no reason why the thickening rate should fall off with time. It now becomes apparent why the oxide film reaches interference color thickness, which is not generally reached in ordinary oxidation processes except at elevated temperatures. Apparently the film resembles high-temperature oxide films in being under internal stress and breaks up when a certain critical thickness is reached (Evans[28]), forming the loose white rings which overlie the color films where they are thickest; the fact that the white matter of the rings shows the same preferred orientation as the color rings indicates that it is formed by the break-up of the film and not dropped from the liquid.

When the liquid contains many zinc ions, they are presumably balanced by hydroxyl ions (the equivalent removal of hydrogen having taken place at the cathode). The solubility of zinc hydroxide (and oxide) is low, and sooner or later the liquid will become supersaturated. It has been shown by Aebi[29] that the least soluble (*i.e.*, most stable) of the possible phases is the ε-hydroxide, but that frequently a metastable phase is first deposited. Whichever compound is first precipitated, the particles,

whilst still of colloidal size, apparently acquire a negative charge by adsorbing hydroxyl ions and thus become stabilized. They migrate by electrophoresis towards the anode and are presumably deposited; this may explain the loosely adherent white matter (probably amorphous) found in the pits.* It is only partially protective—as would be expected—but after a time the anodic attack is stifled, which explains the asymptotic corrosion-time curve established by Bengough, Stuart, and Lee[10, 11, 12]—in contrast with the straight lines obtained in chloride solutions where both anodic and cathodic products are soluble, zinc hydroxide being formed when they meet. Thus the difference in the location of corrosion products, as well as in the character of the corrosion-time equation, is explained.

Electrochemical Action in Badly Conducting Liquids.—A necessary condition for electrochemical action in badly conducting solutions is that *very small* anodic areas shall be surrounded by annular cathodic areas; only in that case can a cathodic area (much larger than the anodic area) exist very close to the anode, keeping the electrolytic resistance small. In general, the ratio of effective cathodic area to anodic area determines the intensity of attack, which explains the sharp pitting produced by distilled water (especially the purest distilled water) on zinc. In more concentrated (and better conducting) solutions the total corrosion is greater but the attack less intense. Any doubts about the possibility of a zinc-oxygen cell with distilled water as electrolyte are dispelled by the experiments with the model cell.

The explanation suggested for the behavior of zinc in distilled water fits the general picture of corrosion and passivity put forward by Hoar and Evans.[30] The same picture explains why alloying additions (*e.g.*, chromium and aluminum) which confer resistance to high-temperature oxidation also prevent wet corrosion. The mechanism now put forward for zinc has points in common with that suggested for tin by Brennert[31] and Hoar.[32]

Subsequent Breakdown of Films.—If the solid product formed both at cathodic and anodic areas is anhydrous zinc oxide, the system is metastable, since the ε-hydroxide is less soluble. If once a nucleus of hydroxide appears, presumably recrystallization will quickly spread and the whole film may become non-protective. This may be the cause of the sudden recommencement of the corrosion of zinc in distilled water, after it has become very slow, as noted by Bengough, Stuart, and Lee[10, 11, 12].

Concentration of Zinc reached in the Whirler Experiments.—According to Feitknecht and Häberli[33] the solubility products $[Zn^{++}][(OH)^-]^2$ are as follows:

Amorphous $Zn(OH)_2$	$3{\cdot}9$—$5{\cdot}5 \times 10^{-16}$
α-$Zn(OH)_2$	$1{\cdot}4 \times 10^{-16}$ (Aebi[29]).
β_1-$Zn(OH)_2$ †	$5{\cdot}0$—$6{\cdot}0 \times 10^{-17}$

ε-$Zn(OH)_2$, the stable form, has naturally a still lower value; Feitknecht[34] gives this as $2{\cdot}7 \times 10^{-17}$ if calculated on conventional principles, and $8{\cdot}4 \times 10^{-18}$ if the Debye-Hückel equation is used.‡ Aebi assigns to the anhydrous oxide a value 7×10^{-17}, corresponding to the equilibrium ZnO (solid) + $H_2O \rightleftharpoons Zn^{++} + 2OH^-$. If 1×10^{-16} is taken as a basis of calculation and it is noted that the water assumes a pH value of $8{\cdot}5$ after the whirling experiment, or a pOH value $5{\cdot}5$, then it is evident that, if the water becomes saturated with zinc oxide (or α-hydroxide), it should contain $10^{-[16\,-\,(2\times5{\cdot}5)]} = 10^{-5}$ g.-ion/1. of zinc, in agreement with experiment. If, however, the stable ε-hydroxide was being deposited, with a solubility product of about 10^{-17}, the agreement would be poor. Actually, since electron diffraction indicates the anhydrous oxide, the results are explained.

* The white matter in the pits might also be due to anodic discharge of hydroxyl ions.

† Feitknecht[35] states that the two forms of β-$Zn(OH)_2$ known as β_1 and β_2 give X-ray patterns differing only in intensity.

‡ The difference between the two values may cause surprise, and the reader is referred to the discussion of the matter by Feitknecht[35] and Häberli,[33] especially pp. 930, 931). For the present purposes the question is not important, since no calculations in this paper are based on the solubility product of ε-hydroxide.

We thank Dr. J. W. Menter for fruitful co-operation in the electron-diffraction work, Dr. W. H. Taylor and Mr. G. J. Dickins for facilities in connection with the *X*-ray studies, and Prof. W. Feitknecht for valuable information regarding diffraction patterns of numerous compounds. One of us (D. E. D.) thanks the Department of Scientific and Industrial Research for a Maintenance Grant.

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Figure 2a—Boiler drum interior showing standby corrosion.

Prevention of Standby Corrosion In Power Plants*

By LEONARD HIGHLEY, JR., and W. R. SCHNARRENBERGER

PREVENTING CORROSION in power plant equipment is usually more difficult when the equipment is idle than when it is in normal operation. If corrosion during idle or standby periods is to be prevented, the circumstances under which it occurs must be understood thoroughly. This discussion will cover the general problem as related to boilers, superheaters and turbines—vital points in any power plant. Several case histories and suggested preventive measures will be outlined.

The General Problem

Essentially, standby corrosion involves the reaction of the surfaces of the equipment involved with moisture or water in which dissolved oxygen and, to a limited extent, carbon dioxide act as accelerators. This results in pitting and general wastage of metal.

It is ordinarily impossible to differentiate between operational and standby corrosion simply by visual or metallographic examination of corroded specimens in the laboratory. The history of operation and the water conditions maintained in the equipment must be known to aid in this differentiation. The location of the attack is of special significance. Owing to these circumstances, it is important that diagnosis be made by persons well qualified through training and experience in such matters.

During operation, most power plants will have potential corrosion in the water-steam cycle under control. This is accomplished by reducing oxygen in the feedwater to very low levels (on the order of 0.03 ppm or less) by means of adequate mechanical deaerating equipment and by maintaining suitable alkalinity in the boiler water. Sodium sulfite is generally employed as a secondary measure for chemical removal of traces of oxygen that may be present in spite of the deaerator. Thus, the equipment in most plants remains substantially free of the dissolved oxygen type of corrosive attack during operation.

When a boiler is taken off the line to be placed in standby, the operators have the choice of draining and maintaining the unit in so-called "dry" standby, or else leaving water in the boiler. This latter practice is followed frequently when the equipment may be needed for operation on relatively short notice, but is especially dangerous from a corrosion standpoint if proper precautions are not followed. As a boiler cools, the internal pressure drops, creating a partial vacuum; all the spaces normally occupied by steam

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Abstract

It is common practice in taking a boiler off the line to do no more than let the fire burn out and allow the water in the unit to assume its natural level. This practice is frequently adopted so the boiler can be placed in service again on short notice. However, if immediate need for the boiler is not anticipated, it is preferable to prepare the unit so that corrosion cannot occur during the idle period, when the boiler is in standby.

Recognizing standby corrosion and distinguishing between it and corrosion occuring during operation are often difficult tasks and require considerable experience on the part of the boiler inspector or plant operator. Specific locations in the boiler are especially susceptible to attack during standby, but under certain conditions any area in the unit may be affected.

A number of case histories are cited to illustrate the complexity of the problem. These describe damage to boilers, superheaters and turbines—vital units of power plant equipment. Reference is made to the pertinent points which establish the fact corrosion occurred during periods of standby.

A number of practical preventive measures are described which have proved effective in practice. These include both dry and wet procedures. For boilers and superheaters the dry method provides the most certain protection. Dry standby entails draining the boiler and keeping it dry during the idle period. When the wet method is used it is essential that the unit be completely filled with properly conditioned water at all times and that circulation be supplied at intervals to insure against dilution resulting from leakage of feedwater or steam condensate into the unit.

Standby protection in the case of turbines will usually involve guarding against steam in-leakage and prevention of siphoning action through drain lines.

Basically, prevention of standby corrosion requires keeping all surfaces of equipment free from contact with moist air or water containing dissolved oxygen. While operating requirements of industrial power plants will vary, suggested procedures will nevertheless serve as guides in preventing standby corrosion.

then become filled with air. The metal exposed to the moist atmosphere in these regions is extremely vulnerable to corrosive attack stimulated by oxygen and carbon dioxide. The problem of preventing such corrosion resolves itself into eliminating either the moisture or the oxygen.

Significance of Location

A conventional 4-drum, bent tube type boiler with non-drainable type superheater is shown in Figure 1. The markings in tubes and drums illustrate the locations where oxygen corrosion usually occurs under different conditions. Those areas marked by the letter "O" represent the surfaces most susceptible to dissolved oxygen corrosion during normal operation, if adequate protection by mechanical and chemical means is not provided. It will be noted that the surfaces involved are essentially those through which the incoming feedwater first passes after entering the boiler; for example, the drum surface below the feedwater trough or pipe and the rear downcomer tubes. In addition, corrosion frequently occurs beneath any sludge that might accumulate in the mud drum.

When a unit is placed in standby merely by pulling the fire and allowing the water to assume its normal level, corrosion can be expected to develop in the areas marked by the letter "X." These vulnerable areas are in the steam circulating tubes, steam offtake lines, superheater headers and tubes and at or slightly below the normal water level in the drums. In other words, corrosion experienced during standby

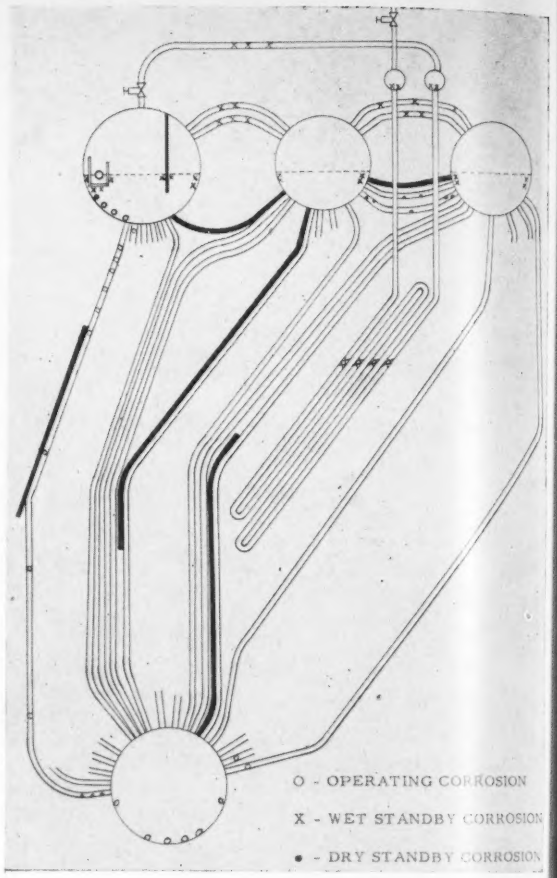

Figure 1—Possible locations of corrosion occurring under different conditions.

is generally found just below the water level and in the spaces normally filled with steam. The marked areas in the superheater tubes were selected arbitrarily to indicate that during cooling of the boiler, as it comes off the line, steam condenses and fills the loops to these approximate levels. A drainable type superheater would, of course, not be affected by such difficulty in this area—provided it is drained.

Quite frequently, boilers are removed from service and placed in "dry" standby. This is accomplished by draining the water and allowing the unit to stand with the manhole and handhole covers open to permit free access of air. However, certain synclinal tubes such as those marked by the black dots in Figure 1 will trap water, and corrosion can proceed unless these tubes are dried out by swabbing after the unit is drained.

Occasionally, due to climatic conditions, external corrosion of the boiler is troublesome. This attack can be expected almost any place on the furnace side of the tubes where condensation may occur, is especially likely to occur where soot and ash accumulations contain sulfur compound and also as a result of leakage from soot blowers on furnace side.

Case Histories

The following instances are cited to illustrate the

wide range of occurrences of standby corrosion but do not give remedial steps, because these will be taken up in detail later.

Boiler Corrosion

I—Figure 2 illustrates two 3-inch OD tube ends removed from a 200 psig boiler. Observe the severe pitting and metal wastage. Until approximately 12 months before this damage was noted, the boiler operated practically continuously and there had been no trouble with corrosion. However, the boiler was not in service for about five out of the twelve months and during the other seven months it operated only five days per week. During the time it was not in operation, no special precautions were taken to minimize corrosion. At times, the boiler was drained and on other occasions the fire was simply allowed to burn out while the pressure dropped to atmospheric. The tube sections illustrated were part of a bank of downcomer tubes, and even though actual failure had not occurred, it was decided that the entire bank should be replaced to insure continuity of future operation.

Ia—Standby corrosion occurring in the steam drum of a 150 psig three-drum bent tube boiler is illustrated in Figure 2a. Note the general attack, especially on the upper row of tube ends. This particular boiler had been operated only a few days each year in emergencies. During standby, a half-hearted attempt was made to supply protection, consisting of filling the boiler with water until the gauge glass was full. Unfortunately, such a practice doesn't insure complete flooding of the unit and it is significant that the elevation where corrosion was most severe corresponds to the upper extremity of the gauge glass. In other words, failure to completely fill the boiler permitted oxygen to accumulate in the upper section of the drum and corrosion proceeded especially at the water level, as discussed previously.

II—An example of standby corrosion experienced in a 900 psig boiler is illustrated in Figure 3. The section shown represents an economizer recirculation line entering the steam drum below the water level and used only during start-up. Additional signs of similar attack were noted in the upper section of the steam drum. The remainder of the boiler was free of corrosion and a careful check of records revealed that the unit had been idle for three months out of the year preceding discovery of the attack.

III—An example of external corrosion is shown in Figure 4. The tube came from a boiler of the cross-drum type operating at 400 psig. At first, it was assumed that the tube eroded due to soot blower action. Closer examination revealed actual chemical attack of the metal. Analysis of a light coal ash deposit on the external side of the tube revealed the presence of ferrous sulfate. At the same time, it was reported that considerable condensation had occurred in the furnace during week-end shutdowns. This combination produced an extremely corrosive environment as would be expected, resulting in ultimate failure.

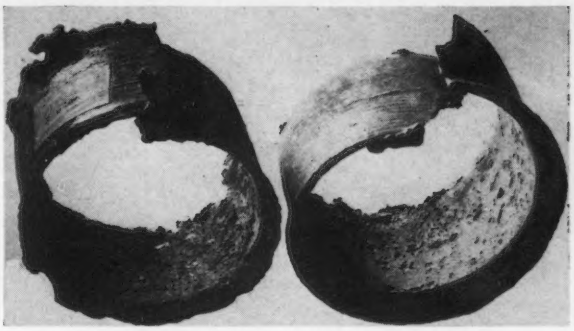

Figure 2—Corroded tube ends from 200 psig boiler.

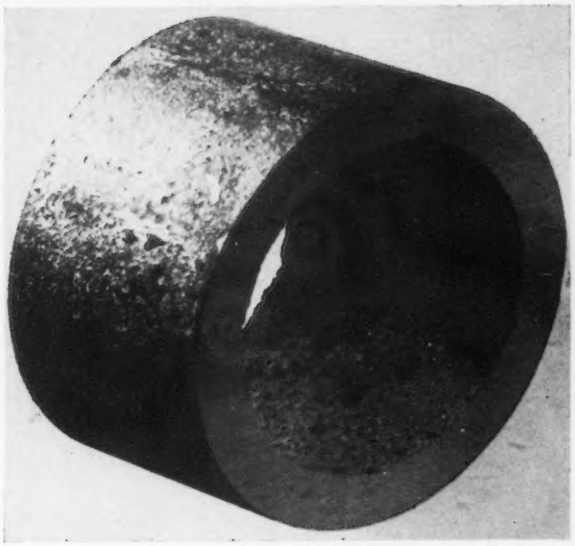

Figure 3—Pitted section of economizer recirculating line from a 900 psig boiler.

Figure 4—Failed section of a generating tube illustrating serious external attack.

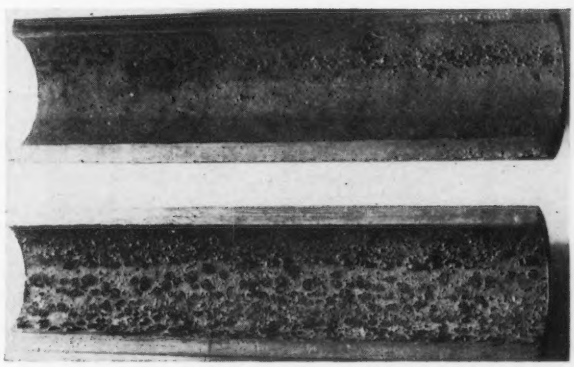

Figure 5—Tubercles and pits in bottom and top halves of a section of chrome-moly superheater tube from a 1325 psig boiler.

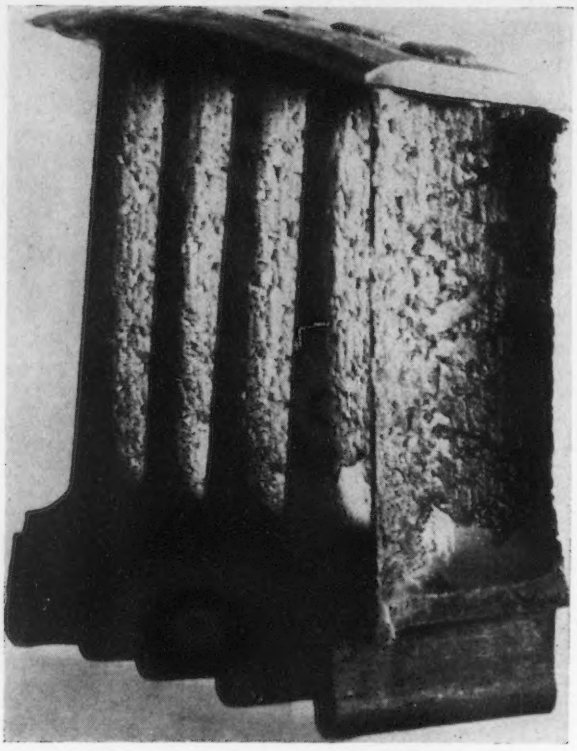

Figure 6—A portion of blading removed from a 400 psig turbine showing corrosion resulting from steam leakage during standby.

Superheaters

IV—As mentioned earlier, superheaters are especially vulnerable to attack, particularly if they are of the non-drainable type. Figure 5 shows corrosion resulting in a non-drainable type superheater tube section of a 1325 psig boiler. The superheater is composed of three sections, each of which is made of a different type metal. The lower section is chromium molybdenum titanium steel, the middle section chromium molybdenum, and the upper section ordinary low carbon steel. All three sections have revealed similar corrosion. The illustration represents a specimen from the chromium molybdenum section. During six years' operation, this boiler had been out of service about 20 percent of the time for external repair work and it was not always possible to provide adequate internal superheater protection during these idle intervals.

Corrosion has been experienced to a lesser degree in the superheaters of two similar boilers at this plant. One of these has been in standby approximately 10 percent, while the other has been idle for 15 percent of the time. It is interesting to note that the severity of attack in these three superheaters is proportional to the length of standby.

Steam Turbines

V—Figure 6 illustrates a severe case of turbine blade corrosion resulting from standby. This specimen came from a 400 psig unit following 16 years of intermittent service. While in operation, it received the same steam as other similar turbines operating continuously. The turbine from which the specimen came is the only one, however, that revealed such attack. Investigation has shown that the corrosion resulted from condensation of steam that had leaked into the machine during standby.

VI—Another interesting case of turbine blade corrosion occurred in a beverage plant. Initially the plant engineers blamed the difficulty on solids in the steam. However, close investigation proved this was not the case. Once the unit was returned to operation, steam purity tests were conducted on the steam going to the turbine and no evidence of carryover was found. Meanwhile, a search was instituted for leakage that could occur during standby. The leak-off connections on the carbon seal rings drained to the barometric condenser hot well. The end of the drain was below the surface of the salt water in the hot well, and there was no check valve in the line to prevent the salt water from backing up into the turbine when shut down. Thus, each time the turbine was down, salt water was siphoned back into the turbine by the vacuum. Also, the drains on the bottom of the turbine terminated in a trap, and it is questionable if this arrangement permitted complete draining of accumulated water.

The turbine has shown excellent internal conditions and absence of any corrosion during subsequent inspections since proper standby precautions have been instituted.

Preventive Measures

Boilers and Superheaters

Standby service requires that one or the other of two sets of conditions be met: Either the boiler must be held in readiness to operate on short notice, or else the boiler will be continuously inoperative for an indefinite period. The former can be designated *intermittent standby,* and the latter as *prolonged standby.*

Under *intermittent standby* the water level maintained in the boiler corresponds closely to that of the operation. By banked fires or reduced firing, the water temperature is held close to that of steaming.

If this status could be maintained, little difficulty would be experienced. However, circulation under these conditions is very slight and some loss of water occurs, possibly through slightly leaking blowdown valves, or by light steaming and this must be replaced by feedwater. If the feedwater is sufficiently oxygen-free and of suitable alkalinity, conditions leading to corrosion will not develop. On the other hand, delayed intermingling of boiler and feedwater and segregation of the latter may produce at some of the boiler surfaces conditions of low alkalinity and dissolved oxygen concentrations which are conducive to corrosion. In cases of lengthy standby and of appreciable makeup of feedwater to replace losses boiler water alkalinity may disappear entirely and general corrosion may occur.

Regular boiler water tests should be made as carefully on the boiler under these conditions as on the operating boilers. If possible, the samples should be drawn from a point close to the section where feedwater enters the boiler. If the alkalinity falls too low, it can be augmented by introducing a small

amount of dilute caustic soda solution directly into the boiler at the point of feedwater entry, with a force hand pump, or in some other convenient manner. In cases where oxygen is dissolved in the feedwater that is introduced, sodium sulfite (Na_2SO_3) is generally pumped into the boiler, either separately, or along with the alkali solution, to react with and remove the dissolved oxygen. Sufficient sulfite should be fed to maintain a concentration of at least 100 ppm as Na_2SO_3.

If corrosion in certain sections indicates segregation of the feedwater the manner of feedwater delivery to the boiler sometimes can be arranged to assure better mixing with the boiler water. If several boilers are maintained in intermittent standby simultaneously, they should be called upon in turn for operating service whenever possible, thus minimizing the irregular conditions that may develop from standby.

The rules that are appropriate in this case, therefore, are quite largely those that apply to operating boilers and must be as fully and carefully followed.

Under *prolonged standby* conditions, two general procedures are available. The boiler may be emptied and dried out and kept dry; or it may be filled completely with water. In the latter case, the drums are filled to the steam offtake.

Draining and drying gives excellent protection to the metal surfaces as long as they remain dry. At times the boiler is left open for free circulation of air after drying and at other times a drying agent such as quick-lime (CaO) or silica gel is placed on trays in the boiler, which is then closed. In either case, water and steam leakage into the unit must be guarded against, because such water saturated with oxygen and in contact with the surfaces promotes rapid corrosion. As long as the surface remains dry significant corrosion will not occur.

Similar moisture-free conditions will protect superheaters of the drainable type. On the other hand, collection of condensate in lower bends of a non-drainable superheater, as described previously, will promote rapid attack even though the boiler proper remains in good condition. To dry the superheater initially, blowing warm air through the individual tubes or elements is suggested. To insure complete drying and elimination of subsequent condensation, a series of small heaters, either gas or electric, should be installed in the furnace at the lower extremity of the superheater bank and equally spaced across its width. Maintenance of such a heating arrangement will insure internal and external dryness of the superheater tubes. This represents the most positive means of minimizing standby corrosion in the superheater whether the boiler proper is left open to the atmosphere or is sealed with trays of quick-lime inside. It should be pointed out that the use of quick-lime requires that the chemical be inspected at about monthly intervals to make certain that it is not caked and spent.

If experience indicates that external sweating of the boiler tubes is a problem, additional heaters should be installed in the furnace at strategic locations to maintain temperatures above the dew point in all parts of the furnace as well as in the superheater section.

The second method of protection during continuous standby is usually referred to as the "wet" method. This procedure gives good protection, provided,

1) the correct chemical conditions are maintained in the water with which the boilers are filled,
2) mixing of the water in the boilers is satisfactory so that fairly uniform concentrations are obtained throughout each boiler; and
3) the boilers are completely filled with treated water so that no inner surfaces are in contact with the air.

Sufficient caustic soda should be added to boilers in wet standby to maintain a sodium hydroxide concentration of approximately 250-400 ppm and enough sodium sulfite should be added to hold a concentration of 100 ppm Na_2SO_3 or even higher. These concentrations are considerably higher than those usually maintained in an operating boiler, for a wider margin of safety is needed due to the possibility of greater oxygen contamination. A convenient method of adding these chemicals is to feed them to the suction of the boiler feed pump as the boiler is being filled, thus assuring thorough mixing. Further circulation of the water in the boiler is also required so that correct chemical conditions will exist in every section of the unit during standby. This is sometimes accomplished by means of a pump which circulates water from one section of the boiler to another.

If a circulating pump is not available, mixing can be accomplished by light steaming. In some cases where operating boilers are to be taken out of service to stand idle for some time, the correct concentrations of alkalinity and sodium sulfite can be built up in the boiler water before the boilers are taken off the line.

No matter how mixing is accomplished, samples drawn from various sections of the boiler should be tested periodically to determine whether or not concentrations of alkalinity and sodium sulfite are satisfactory.

If possible, deaerated water should be used to fill the boilers. Other sources can be used if deaerated water is not available. In any event, chemical analysis should be made on the water immediately so that protective chemical concentrations are established without delay.

In completely filling the boilers, the superheaters as well should be filled. Also, all values—blow-off, non-return, water column and feed—should be tight to minimize leakage of water out of or into the boilers.

A convenient method of maintaining a boiler full of water is illustrated by Figure 7. A small tank of 25-50 gallons capacity and located above the boiler is filled with water containing the proper amount of alkalinity and sodium sulfite and connected to an available connection on top of the boiler or on the superheater outlet header. With this arrangement, water leaking from the boiler will be replaced by water from the tank and if the tank is kept filled

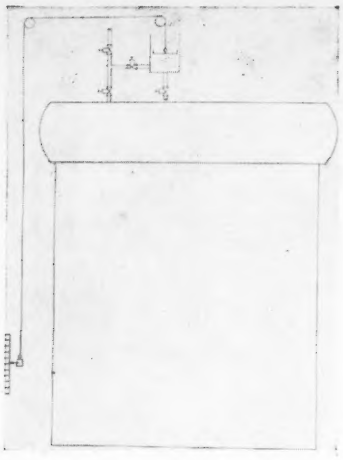

Figure 7—Sketch suggesting a method of maintaining a boiler in wet standby.

the boiler will always be full. On the other hand, if leakage of water into the boiler occurs the tank will overflow and this will be an indication that steam or water inleakage is occurring. A close fitting, floating cover is provided for the tank arrangement on top of the boiler, being connected by means of pulleys and light chain to an indicating device at the operating floor level. This provides the operators with a continuous indication of the water level in the tank without necessitating their climbing to the top of the boiler.

Turbines

The most effective and fool-proof method of preventing standby corrosion in turbines consists of double valving all steam connections to and from the turbine, such as inlet steam line, extraction lines etc. Tell-tales should be installed between the double valves as a check on leakage. In addition, drain lines should be inspected to make certain they are open ended to permit positive drainage of accumulated condensate. It helps greatly if warm air can be blown through the unit continuously to maintain the temperature above the dew point. In a number of instances, this has been accomplished by an arrangement consisting of a small fan blowing air heated by electric lamps or heaters into the inlet of the turbine at a point following the double valves.

Another procedure that could be used for accomplishing the same purpose is to fill the turbine with nitrogen gas and continuously bleed the gas through the turbine at a slow rate.

Conclusion

Basically, the prevention of standby corrosion requires maintaining all surfaces of the equipment free from contact with water containing dissolved oxygen. While operating requirements of industrial power plants will vary, the suggested procedures will nevertheless serve as guides in preventing standby corrosion.

DISCUSSIONS

Question by L. C. Case, Gulf Oil Corp., Tulsa, Okla.:

Since a boiler should be completely full of fluid in standby condition, why not use a solution of sodium chromate and forget about oxygen present?

Author's Reply:

Sodium chromate should be effective during standby, as long as the equipment in question is completely filled or flooded with chromate treated water in the manner similar to that prescribed in our paper. However, when the equipment is returned to service, the reduction of chromate radical to chromium ion will result in the boiler water taking on a rather dark green color and this in itself is objectionable from the standpoint of obtaining accurate endpoints during the course of regular boiler water testing. At the same time, our experience indicates that sulfite is a more effective agent for minimizing oxygen corrosion than is chromate during operation. Since chromate and sulfite cannot be employed for effective water treatment simultaneously, only one of these materials can be used at a time. For these reasons, it is our opinion that chromate treated water employed during standby should be dumped or removed as rapidly as possible through blowdown and replaced, preferably with deaerated feedwater, when operation is resumed.

Comments by Marc Darrin, Mutual Chemical Co. of America, Baltimore, Md.:

In further reply to L. C. Case's question I would like to add that chromate is particularly effective for preventing corrosion during idle periods and that, when a high pressure boiler (over 250 psi) is returned to operation, the chromate is quickly reduced to a hydrous chromic oxide which is deposited as a very thin and if anything slightly protective film on the inside of the tubes and boiler drum.[1] For this reason it is unnecessary in most instances to remove chromate solutions from standby boilers before firing. The proportion recommended is 200 ppm or about two pounds of chromate per 1000 gallons.[2] For systems having small pipes with dead ends or crevice-like stagnant regions where the ratio of metal surface to liquid volume is large and into which chromate might not diffuse as rapidly as it is consumed, higher concentrations should be used, up to 1000 ppm. Of course after a long period "in moth-balls" it is desirable to completely flush before placing in operation.

With low pressure boilers (up to 150 psi) rusting can be eliminated by using chromate during both idle and active periods. For this application it is recommended to maintain a concentration of 300 to 400 ppm by checking the blowdown once or twice a week. This may be judged in most instances with sufficient precision by depth of yellow color. An excess of chromate does no harm. Of course when using an oxidizing inhibitor such as chromate, nothing is gained by deaeration since this type of inhibitor, if anything, functions best in the presence of oxygen. As would be expected chromate is incompatible with reducing additives such as sulfite,

but it may be employed with most other compounds which are used for boiler water treatment. At Mutual's Baltimore plant excellent results are obtained by maintaining a concentration of 300 ppm of sodium chromate in the blowdown. Inspection of tubes after more than 25 years of service shows no rust or other signs of corrosion. These boilers generate steam at 100 to 150 psi.

In small low-pressure boilers used for store and house heating, it is customary to add a large excess of chromate so as to make it unnecessary to check more than once a year. For this purpose it is common to add about 4 ounces of chromate per 100 sq. ft. of radiator surface, or per 15 gallons of water capacity, and maintain a concentration of 1000 to 2000 ppm. In order to avoid any possible misconception it should be kept in mind that chromate is non-volatile, hence incapable of protecting above the level of the water. Furthermore, chromate is not a water-softening agent. Its sole function in boilers is to inhibit rusting below the water line.

References

1. R. C. Ulmer and J. M. Decker. *Combustion*, **10**, 31-3 (1928).
2. Marc Darrin. *Ind. & Eng. Chem.*, **37**, 741-9 (1945); *Oil & Gas Jour.*, **47**, 85 (1949) Feb. 3.

DISCUSSION

Remarks by G. N. Andrews, Utilities Dept., Shell Oil Co., Wood River, Ill.:

What method do you suggest to prevent corrosion of the external surfaces of boiler tubes or drums during standby? In some cases we have laid up several 252 horsepower single-drum longitudinal tube type boilers and several 522 horsepower four-drum bent tube Stirling type boilers using an oil spray to paint the outside surfaces of the tubes to prevent undue corrosion. These boilers are natural draft units connected to a single 225-foot concrete stack.

Author's Reply:

We appreciate Mr. Andrews' comments concerning protection of external surfaces during standby. Application of a suitable oil spray to paint the outside surfaces of the tubes should give satisfactory protection, so long as all surfaces are covered thoroughly. In cases of excessive sweating, such as can be experienced in high humidity sections of the country, the oil coating may be washed away in time. However, use of small electric or gas heaters as outlined in our paper, should provide positive protection continuously with a minimum of attention.

Discussion by Franklin McDermott, Lever Bros., New York:

"Is a short shutdown equally important in standby corrosion?" Is there a possibility there may be a lag in the inception of corrosive attack and that a number of week-end shutdowns produce less attack than continuous exposure of equal time length?

Author's Reply:

In reply to Mr. McDermott's question pertaining to the comparative corrosion rates between week-end shutdowns, for example, and periods of several weeks or more, our experience indicates that, everything else being equal, the total elapsed time is the important factor. In other words, a boiler in standby for two days every week for a year, or a total of 104 days, will show about the same amount of corrosion as a similar boiler which operates continuously for 261 days and then is idle for standby for the remainder of the year. As a matter of fact, some of the most serious cases of standby corrosion that we have noted have been in smaller boiler plants where the equipment is operated at low pressure and cut out of service overnight and over week-ends. Three separate plants come to mind where such an operating schedule was followed and no precautions taken to prevent air being drawn back into the boiler. In all cases, it was necessary to completely retube these units within a matter of two to three years. While raising alkalinity and sulfite concentrations during such short standby periods is difficult, nevertheless, the practice of simply flooding the boilers after the pressure had dropped to zero was sufficient to practically eliminate the difficulty. Admittedly, these were small boilers but the experience serves to illustrate the point at hand.

Anonymous Remarks:

The authors have made a very worthwhile contribution to maintenance of boiler plant equipment by again calling attention to the importance of adequate safeguards against corrosion of idle boilers and turbines. Diligent efforts to prevent corrosion during operating periods by mechanical deaeration and chemical treatment may be largely negated by failure to realize the importance of proper lay-up practice.

In the wet method of boiler lay-up for prolonged periods, it may be found advantageous to provide even higher chemical excesses than those suggested in this paper—perhaps as high as 500 ppm sodium sulfite and as high as 1000 ppm sodium hydroxide alkalinity. The small amount of additional chemicals required will give further safeguard against depletion of sulfite by oxygen ingress in the intervals between tests of the water. This will also help to compensate for non-uniform distribution of chemicals throughout the boiler water. The addition of lignin or tannin materials at the rate of about one pound per 1000 gallons of holding capacity of the boiler has also been found to be of benefit due to the staining or film-forming ability of the chemicals.

Economics of Industrial Maintenance Painting*

By ROBERT R. PIERCE*

Abstract

Data are based on results of a continuing research program, initiated by the Corrosion Engineering Products Department of the Pennsylvania Salt Manufacturing Company some eighteen months ago to determine factors and materials which promote maximum protective life in chem-industrial painting. This research includes 429 individual studies of the protective value of 62 maintenance painting compositions of 10 different basic types.

Determinations have all been conducted within the operating process areas of three major chemical manufacturing plants, widely divergent geographically, in fourteen different environments. Wire brushed, corroded and blasted surfaces have been examined. No artificial or simulated exposures were used in any phase of the program.

Where performance comparisons were required and in order to determine performances over surface irregularities normally encountered in maintenance painting, a new type test panel was used. The reliability of results from these panels was confirmed by 101 individual paint applications to actual operating plant equipment and structures. During the course of this program, actual and projected protective life expectancies of various painting systems and procedures were determined and converted to direct dollar cost and savings.

Some results from this program included in this article are:

1. Over 60 percent of the industrial maintenance paint compositions which by long experience have proved their adequacy in straight industrial use will fail rapidly when used for maintenance painting in a chem-industrial exposure.
2. Surface preparation by blasting will increase by two to four times the protective life of the maintenance paint system over wire brushed, corroded surfaces.
3. Maintenance paint system thicknesses below 5 mils are undependable in aggressive chem-industrial environments.
4. Regular schedules of paint inspection and repair can reduce cost of plant protection to the magnitude of 5 cents per square foot per year even in aggressive chem-industrial exposure.

EARLY IN 1950, the Pennsylvania Salt Manufacturing Company initiated a study of industrial maintenance painting within its own chemical manufacturing plants. The purpose was to study the basic principles of maintenance painting procedures.

This program, still continuing, has included examination of the performance of 62 different maintenance paint formulations representing ten different basic types of coatings. Performances are compared over both sand blasted and corroded, wire brushed surfaces. Exposure studies include 14 different locations in three of our chemical plants in widely separated areas of the country. These exposures range from relatively mild yard weathering stations to the aggressive action of moist hydrofluoric acid fumes. These stations include such aggressive corrosive conditions as the manufacture of chlorine, sulphuric acid, hydrochloric acid, ammonia, chloride and sulfate salts and chlorinated organics.

To date, 429 individual studies have been completed and additional studies are being initiated each month. The data in this paper are based on 337 of these studies which have revealed significant information and include the performances of oleoresinous, bitumin, wax, vinyl, furane, epon, phenolic, polystyrene and synthetic and chlorinated rubber systems. All exposures are actual plant exposures.

Early studies were made by a crossword puzzle design of paint patches on actual plant equipment. This method was found unreliable due to differences in the intensity of aggressiveness from one patch location to another. Later, a special panel was adopted which has proven reliable in measuring paint performance. Paint systems and procedures which show promise on the panels are then applied to plant equipment and structures. To date, 101 such plant applications have been made and fully confirm data derived from panel studies.

The panel, shown in Figure 1 is constructed of SAE 1020 steel plate and bar channel to contain all of the factors commonly encountered in plant maintenance painting. Welds are made with AWS E6010 rod using 25 percent penetration with normal spatter. As the panel represents surfaces identical to plant operating equipment and structures, no acceleration of paint deterioration may be expected. However, by

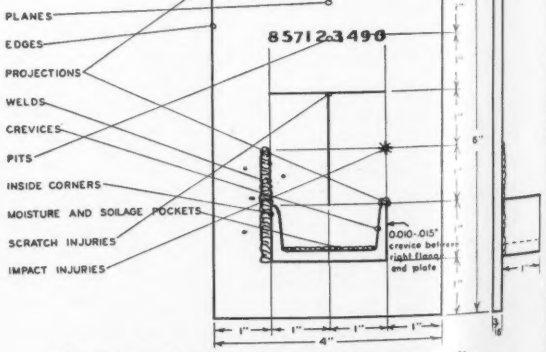

Figure 1—Special type test panel used in paint studies.

★ A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952.

* Corrosion Engineering Products Department, Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.

Figure 2—An exposed test panel.

Figure 3—A corroded test panel, to be wire brushed and painted.

observing the paint performance over sharp edges, welds and projections, early indications of performmay be obtained. This may be observed in Figure 2 which shows a test panel after exposure.

Also, acceleration of results is accomplished by locating the panels close to the source of the deteriorating fumes or atmosphere. By use of the panel and paint application procedures, paint performances can be classified within a six months' exposure period. Obviously unsatisfactory systems can be eliminated by performance after four to eight weeks' exposure and any system which shows no deterioration after 20 weeks' exposure has proved to give superior performance in actual plant use. All the data in this paper are based on coatings which have been on exposure for a minimum of 22 weeks.

Systems which show promise over sand-blasted surfaces are re-exposed on corroded, wire-brushed panels to determine their ability to maintain protection under less favorable conditions. Figure 3 shows a corroded panel prior to wire brushing and painting.

While this research program has reconfirmed many well-known principles of maintenance painting it has also disclosed a number of principles which are not universally recognized. Because all these results cannot be described at length in an article of this kind, it is necessary to concentrate on a few points which, if practiced, will allow longer paint service life, at lower cost.

The figures given in Table I represent a mean average of maintenance painting costs within the chemical industry. A reasonable figure for surface preparation is 15c per sq. ft., for paint application 3c per sq. ft. per coat and ½c per sq. ft. for scaffolding and incidental costs. Material cost will average 2æc per sq. ft. per coat.

Based on these averages, Figure 4 shows the direct increase in applied costs with the number of coats applied.

It is recognized that the minimum number of coats required to insure holiday-free coating systems is three. As an average the minimum direct cost of paint applied is 32c per sq. ft. Deviation from this cost depends upon the individual service condition being considered.

Generally, however, it is hard enough to get three coats properly applied without insisting on more. There are available several satisfactory three-coat systems so this discussion will be confined to a study of such systems for general plant maintenance. For general use, catalyzed, accelerated or baked coatings or paints requiring special mixing or compounding of treatment, cannot usually be justified. Such special coatings are economical in certain conditions such as inaccessible areas, areas subject to constant splash and spillage and exceptionally severe corrosive fume conditions.

Figure 5 illustrates the probability of early paint failure at various dry coating thickness as recorded by 337 studies of 62 different paint formulations under a variety of exposures.

In all uses, it should be kept in mind that each additional coat over the justified minimum of three will increase maintenance painting costs by an average of 17 percent. Therefore, it is desirable to keep the number of coats for any use down to the economic minimum. This can be accomplished by proper selection of the coating system and by appreciation of the importance of dry film paint thickness.

TABLE I
Variation in Direct Costs of Painting with Number of Coats
Direct Costs (Cents per square foot)

No. of Coats	1	2	3	4	5	6	7
Material	2.5	5.0	7.5	10.0	12.5	15.0	17.5
Surface Preparation	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Application	3.0	6.0	9.0	12.0	15.0	18.0	21.0
Scaffolding, Misc.	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Direct Cost	21.0	26.5	32.0	37.5	43.0	48.5	54.0

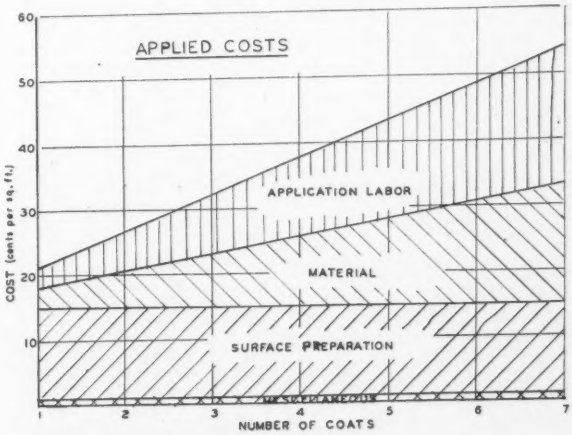

Figure 4—Effect of number of coats applied on paint costs.

It is believed that dry paint film thickness is more important than the number of coats. The number of coats is of concern only in minimizing the possibility of holidays.

These studies include virtually all recognized paint systems and some new systems. The coatings were applied according to the instructions of the manufacturer. Criteria for early failure was definite deterioration over edges, welds and projections within ten weeks of exposure.

From Figure 5, it can be seen that if no minimum thickness specification is considered, the probability of procuring useful protection from recognized systems is only 58 percent. No appreciable improvement is obtained by increasing the minimum thickness to 3 mils, but between 3 and 5 mils there is a marked improvement. Between a minimum thickness of 5 and 6 mils, the curve flattens off at failure probabilities of less than 10 percent. It may be concluded that minimum thickness for successful performance should be set at not less than 5 mils total dry film thickness over a corrodible metal base.

While some variations were recorded for different exposures and different basic types of paint, none were of sufficient magnitude to justify an exception to the data shown in the figure. Although it has been shown in the literature that lower film thicknesses are successful, work reported here indicates 5 mil thickness is necessary to secure adequate protection over the sharp edges, corners, projections and other surface configurations.

Verification of this 5 mil rule was definitely recorded in the studies of paint performance on plant equipment.

Figure 6 shows two acid storage tanks, both painted with the same chlorinated rubber paint system over sand-blasted surfaces. Paint on the tank on the left measures 10 mils and shows no deterioration after three years of exposure. The paint on the tank at the right measures 3 mils and shows numerous patches of rust after two years of exposure.

Figure 7 shows two more acid storage tanks in the same bank as those of Figure 6. Both tanks were coated at the same time, with the same vinyl system over sand-blasted steel. Paint on the tank at the left measures 6 mils and is in excellent condition after 18 months. Both tanks had the same number of coats but the paint thickness on the tank on the right measures between 3 and 4 mils and started to show rust breakthrough after 18 months' exposure.

Minimum thickness, therefore, should always be made a part of any paint application specification. determinations of thickness can be quickly and easily made by a pocket Elco type gauge or the portable G. E. thickness gauge.

Sixty-two paint coatings in these studies represent a cross-section of the chemical resistant maintenance coatings available on the current market, and were applied as three-coat systems according to recommendations of the manufacturers.

The data summarized in Figure 8 reveal that paint systems offered today fall predominantly between 3 and 4 mils, or an average of 1 to 1.3 mils per coat.

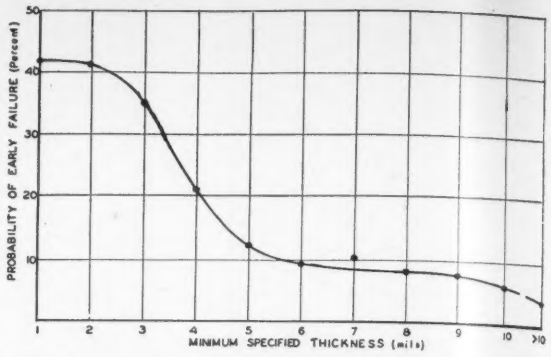

Figure 5—Relationship between paint film thickness and probability of early failure.

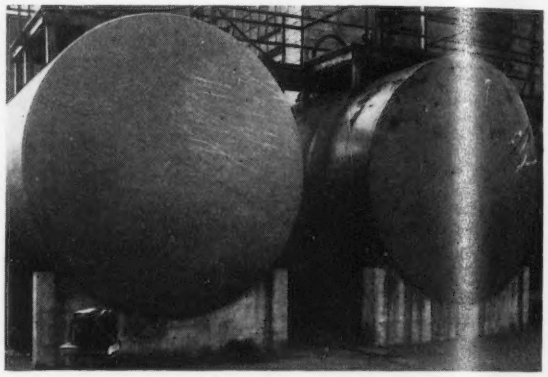

Figure 6—Paint film thickness of 10 mils on tank at left gives better protection than 3 mil film on tank at right.

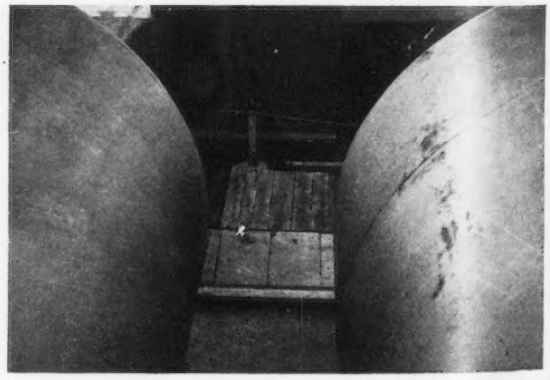

Figure 7—Inadequate film thickness on tank at right results in early breakthrough of rust.

Random buying without regard for film thickness will result in only a 42 percent chance of obtaining a paint system which will yield a safe 5 mils. Such random buying will probably produce a system requiring five coats to exceed the minimum 5 mil thickness.

The cost of such a random system would average 43c per sq. ft. as compared to 32c per sq. ft. for a judiciously selected system. Therefore, "build per coat" is an important consideration in the purchasing and application of maintenance paint. Without resorting to special application techniques, oleo-

resinous coatings will generally vary from 1 to 2 mils per coat. Most synthetics such as vinyls, polystyrenes, epon, furane and phenolic maintenance paints, most chlorinated rubbers and many synthetic rubbers will range between ½ to 1½ mils per coat. A few bitumins, synthetic rubbers and chlorinated rubbers may be depended upon to yield consistently higher thicknesses than 2 mils per coat.

When it is considered that a good system is generally dependent upon the use of a special primer of lower build and consequently a lower thickness, it is apparent that an economical three-coat system must make use of top coats which consistently yield 2½ mils per coat or greater.

Purchasing techniques generally cover consideration of price and coverage per gallon, which by simple division yields material costs per sq. ft. per coat. That this method of cost study is unsound is shown in the following example of two widely used paint systems which are representative of two basic types.

System A, Table II, is a synthetic system with an industrial list of $5.00 per gallon. It has an average coverage of 200 sq. ft. per gallon and yields a normal dryfilm thickness of one mil per coat. No primer is recommended with this system.

System B is a synthetic system specially formulated to yield 3 mils per coat with brush or spray application. Its cost is $7.25 per gallon, with a 150 sq. ft. per gallon coverage. Using the average costs previously given it is seen the apparently inexpensive coating System A actually costs 18 percent more than the apparently expensive System B. This is due to the fact that five coats of System A are required to obtain 5 mil thickness, whereas System B requires only three coats. Also, it is probable that the 6½ mil Sys-

TABLE II

Comparison of Maintenance Painting Costs Using Different Paint Systems

	System A	System B
CHARACTERISTICS:		
Prime Cost per gallon	.....	$5.50
Coverage	.....	250 sq. ft./gal.
Thickness per coat	.....	0.5 mils
Body Cost per gallon	$5.00	$7.25
Coverage	200 sq. ft./gal.	150 sq. ft./gal.
Thickness per coat	1 mil	3 mils
Material cost per coat for prime	.....	2.2 c.
Material cost per coat for body	2.5 c.	4.8 c.
Number of coat to build up 5 mils	5	3
Paint thickness obtained	5 mils	6½ mils
APPLIED COSTS FOR SYSTEM (Cents per Square Foot):		
Material	12.5 c.	11.8 c.
Surface preparation	15.0	15.0
Application labor	15.0	9.0
Scaffolding, misc.	0.5	0.5
Total direct applied cost	43.0 c.	36.3 c.

TABLE III

Twelve Year Paint Maintenance Costs

Cost per Square Foot (Cents)	Initial Application	Scheduled Touch-Up Biennially	Non-Scheduled Repaint Triennially
Material	12.5	2.5	12.5
Surface preparation	15.0	1.5	15.0
Application labor	15.0	3.0	15.0
Scaffolding, misc.	0.5	0.5	0.5
Direct Total Costs:			
Per operation	43.0	7.5	43.0
Cost in 12 years	43.0	37.5	172.0
Cost in 12 years	80.5		172.0
Cost per year	6.7		14.3

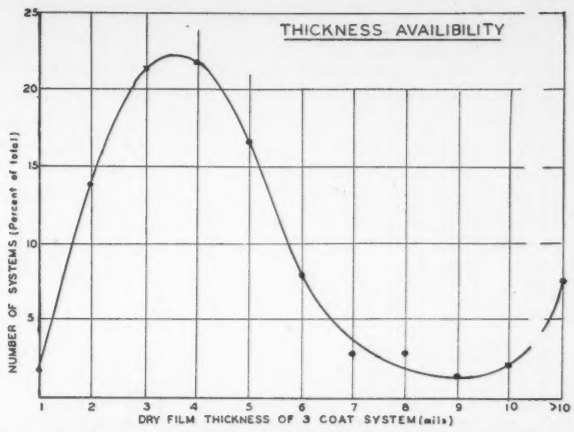

Figure 8—Thickness characteristics of paint systems currently available.

Figure 9—Touching up first indications of localized failure, as shown here, will result in substantially reduced maintenance painting costs.

Figure 10—Rapid deterioration and rust formation illustrated here follows failure to make local repairs.

tem B will give longer service life than the 5 mil System A.

As has been mentioned surface preparation represents approximately 50 percent of an average applied cost of 32c per sq. ft. This expensive operation need not be repeated provided it is properly done initially and that touch-up schedules are established.

Such scheduling requires that a definite inspection system be established and that local wire brushing, spot priming and cover coating be done as soon as inspection shows the slightest indication of localized failures. (See Figure 9.)

It is recognized that once failure starts, general deterioration will be greatly accelerated. If the clean metal surface is always protected by a sound continuous protective paint film, paint life can be extended five or tenfold.

If, on the other hand, a paint is allowed to deteriorate, until rust formation is thick and covers large areas (See Figure 10) complete surface preparation must be included in each paint renewal.

A comparison of costs by each of these methods in Table III shows that maintenance painting costs will be reduced to as much as 50 percent by the simple scheduling of regular periodic inspection and repair.

It has been found that there is no one formulation which is resistant to all of environments represented in 14 different exposures tested, although many types have greater universality than others. Selection of paint types and formulations for each intended use will pay dividends and give increased service life.

Sand blasting will increase paint life two to four times over that obtained by wire brush surface preparation. In highly contaminated areas slow drying paints should be avoided. Intercoat contamination will impair the completeness of the paint film.

Though these results were obtained in chemical industry exposures, it is felt the principles demonstrated will apply to less aggressive environments although the rates of deterioration would naturally be slower.

A New British Corrosion Organization★

By T. P. HOAR*

Abstract

The Corrosion Group, a division of the Society of Chemical Industry, was inaugurated in 1951. Objects of the group are to provide a means of communication among chemists, metallurgists, engineers and others concerned with the research and technical aspects of corrosion and to increase the knowledge of corrosion.

Being a part of the Society of Chemical Industry, the Corrosion Group has available for publication of reports of lectures and discussions and other news, the weekly *Chemistry and Industry*. Original papers are published in the monthly *Journal of Applied Chemistry*.

The Corrosion Group, modeled after the National Association of Corrosion Engineers, is the result of a long-felt need for a means of discussion of corrosion matters in the widest sense. While corrosion problems form only a small part of the activities in the discussions and publications of British technical societies, the Corrosion Group is devoted solely to corrosion and all phases of corrosion are discussed under its aegis.

Idea for the Corrosion Group came originally from Dr. R. B. Mears when he was president of NACE. Dr. Mears suggested to Dr. W. H. J. Vernon of the Chemical Research Laboratory, Teddington and to Dr. U. R. Evans of Cambridge University that an organization be formed in England, such as a section of NACE. However, geographical and other difficulties being considered, the Corrosion Group was thought best suited to Great Britain's needs.

One aim of the group is to make a career in the field of corrosion prevention more attractive to young scientists just starting their life's work, and to create opportunities for visits and exchange students and sponsoring of corrosion courses in universities.

THE CORROSION GROUP, a subject division of the Society of Chemical Industry, was inaugurated in the summer of 1951. The objects of the group are to foster the advancement of knowledge of corrosion and of means for its control and prevention and so to aid progress in conserving metals; a particular object is to afford means of communication among chemists, metallurgists, engineers and others concerned with the research and technical aspects of these matters.

It happened that the author had the good fortune in early 1951 to see something of the work of the National Association of Corrosion Engineers and of the Sea Horse Institute, before returning to Britain in time for the official birth of the Corrosion Group. Consequently, it is a particular pleasure to be able to give U. S. readers some account of the inception and aims of this new corrosion organization.

The desire to have a platform for the specific discussion of corrosion matters in the widest sense is by no means new among corrosion workers in Britain. Although the discussions and publications of the Chemical Society, the Society of Chemical Industry, the Faraday Society, the Institute of Metals, the Iron and Steel Institute and many other bodies have always been readily available for corrosion topics, the particular interests of these societies have

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necessarily limited the type of corrosion work they are in each case prepared to report and moreover corrosion matters form only a small section of the total interests of each society.

With the formation within a single society of the Corrosion Group, having very wide terms of reference, any and all corrosion matters, whether fundamental or practical, chemical or metallurgical, ferrous or non-ferrous, can be discussed and reported under one aegis and this wide scope may well make it an important part of the activities of the Society of Chemical Industry. Furthermore, the title, "Corrosion Group" immediately makes a clear impact on industrialists, publicists and educational authorities, indicating that here is a wide subject for the serious attention of those concerned with the general welfare of industry and of learning. The formation of the group is especially appropriate at present, when the conservation of metals and alloys has assumed such vital importance.

A brief account of the conception of the Corrosion Group may be of interest. Although, as mentioned above, many in Britain have had long-standing feelings that some form of corrosion organization should be established, no concrete steps were taken until a year or two ago. The then president of the recently formed National Association of Corrosion Engineers, Dr. R. B. Mears, had informally suggested to Dr. W. H. J. Vernon of the Chemical Research Laboratory, Teddington and to Dr. U. R. Evans of Cambridge University, that some form of British corrosion organization, such as a section of the National Association of Corrosion Engineers, would serve a useful purpose. Dr. Vernon and Dr. Evans and their many colleagues in corrosion circles, felt somewhat loth either to form a British section of the U. S. association with the attendant geographical difficulties, or to found yet another publishing society, which might merely add further to the deplored dispersion of new corrosion knowledge, while at the same time becoming involved in all the post-war difficulties of publications. However, another possible development arose, primarily from a discussion between Dr. Vernon and Mr. Stanley Robson, then president of the Society of Chemical Industry—the suggested creation, as a new subject division of the society, of a Corrosion Group having terms of reference that would provide for a generous degree of autonomy within the framework of the body. This idea at once commended itself to a large number of British corrosion workers as a basis for the organization most suited to British needs.

The inaugural meeting of the group was held on 17th May, 1951, when Dr. U. R. Evans, F.R.S., delivered the inaugural lecture entitled "The Corrosion Situation—Past, Present and Future" at the Royal Institution, kindly put at the group's disposal for the occasion by the managers. The very large audience of members of the Society of Chemical Industry and friends received (with acclamation) Dr. Evans' stimulating discourse, in which he emphasized the need for properly trained "corrosionists" by nearly all industries. Nearly all established corrosion interests were represented at the meeting and the following representative committee of the group was appointed to hold office during the 1951-52 session:

Chairman: W. H. J. Vernon, O.B.E., D.Sc., Ph.D., F.R.I.C., Head of Corrosion of Metals Group, Chemical Research Laboratory, Teddington.

Vice-Chairman: J. C. Hudson, D.Sc., D.I.C., A.R.C.S., F.I.M., Head of Corrosion Laboratory, British Iron and Steel Research Association, London.

Inaugural Lecturer: U. R. Evans, M.A., Sc.D., F.R.S., Reader in the Science of Metallic Corrosion, Cambridge University.

S. C. Britton, M.A., Head of Corrosion Section, Tin Research Institute, Greenford.

F. Fancutt, F.R.I.C., M.I.Chem.E., Superintendent (Chemistry Division), The Railway Executive Research Department, London.

C. E. Richards, F.R.I.C., Senior Principal Scientific Officer, Post Office Engineering Department, Research Branch, London.

H. T. Shirley, B.Sc., F.R.I.C., F.I.M., Chief Chemist, Brown-Firth Research Laboratories, Sheffield; Chairman of Corrosion Committee, British Iron and Steel Research Association.

T. H. Turner, M.Sc., M.I.Mech.E., M.I., Loco.E., F.I.M., Superintendent (Metallurgy Division), The Railway Executive Research Department, Derby.

F. Wormwell, M.Sc., Ph.D., Head of Immersed Corrosion Section, Corrosion of Metals Group, Chemical Research Laboratory, Teddington.

Hon. Treasurer: W. E. Ballard, F.R.I.C., F.I.M., Managing Director, Metallisation Ltd., Dudley.

Hon. Recorder: P. T. Gilbert, Ph.D., A.R.I.C., A.I.M., Head of Corrosion Section, British Non-Ferrous Metals Research Association, London.

Hon. Secretary: S. G. Clarke, Ph.D., D.Sc., A.R.I.C., Head of Corrosion Section, Metallurgy Branch, Armaments Research Establishment, Woolwich.

One of the first activities of the committee was to arrange a program of meetings for the 1951-52 session. These are being held at approximately monthly intervals, mainly in London, although it is intended to hold meetings at other centers as occasion arises. The first meeting, a general discussion on "Corrosion Problems in Industry" appropriately opened by Dr. Vernon, filled the Chemical Society's lecture room to overflowing and the exchange of ideas by many who might not otherwise have met was held to be of great benefit to all. At the second meeting, in Birmingham, Mr. J. Welsh lectured on "Corrosion in Gas-Burning Appliances," and there was much useful discussion. The third meeting, a discussion on "The Corrosion of Buried Metals," held in London jointly with the Iron and Steel Institute, in conjunction with the British Iron and Steel Research Association, attracted an audience of over 300; there were several original papers, notably on the anaerobic corrosion of iron and steel and on cathodic protection—the latter a topic, until now somewhat neglected in Britain, that is rapidly attracting serious attention by British scientists and engineers. The fourth meeting, at which Prof. G. I. Finch lectured on "The Electron-Optical Study of Corrosion," again attracted a large audience in which industry was prominently represented; a most comprehensive lecture, in the course of which Prof. Finch reported new results with a high-voltage electron-diffraction camera, was followed by an extended discussion opened by Dr. E. A. Gulbransen, whom the group were delighted to welcome at the outset of his stay in Britain. The remaining meetings in the 1951-52 session are to be devoted to: Papers and discussion on "Protective Coatings Under Conditions of At-

mospheric Corrosion," by several authors. Papers and discussion on "The Prevention of Corrosion in Packaging," by the Corrosion Group, Chemical Research Laboratory, Teddington.

It may be seen that, in accordance with its professed purpose, the Corrosion Group has attempted the widest possible program in its first year and this policy should be the means of attracting all those with corrosion interests, whatever their specialties.

With regard to publication, the Corrosion Group, in common with well established subject groups such as those for agriculture, plastics and food, has the great advantage of using the existing publications of the Society of Chemical Industry. Reports of lectures and discussions, general news and committee matters appear in the weekly *Chemistry and Industry*, original papers in the monthly *Journal of Applied Chemistry*. It is not to be expected—nor would it be desirable or possible—that all major British corrosion researches should appear in the *Journal of Applied Chemistry;* but the author personally believes that an increase in the number and scope of corrosion papers published in that journal will have at least one very favorable result—namely, that industrial chemists, organic, inorganic and physical, will become increasingly aware of the interest and importance of corrosion problems and of the amount of skillful effort that is being devoted to them.

An important part of the group's purpose is to bring its influence to bear not only on other scientists but also on the general public, especially those responsible for industrial, economic and education policies. It has long been emphasized, within corrosion circles, that attention to corrosion problems by qualified corrosion workers can often have a profound influence on an industry's and therefore on the nation's economy. The canalization of thought and knowledge through an authoritative group ought to assist industrial and educational leaders considerably in framing policy where the prevention of corrosion and education in corrosion matters are concerned. One of the first results of the inauguration of the group were a number of comments in the national press upon Dr. Evans' inaugural lecture. A more general realization of the importance of corrosion as a factor in national life will, one feels sure, be considerably quickened by the group's function as a go-between for corrosion specialists and leaders in general affairs. In the educational field, the group is now associated (through its committee) in an advisory capacity with schemes of corrosion education in technical colleges and elsewhere. It seems likely that advisory activities of this kind may further develop in due course.

Another function of the Corrosion Group will be to arrange official contacts with similar bodies in other countries. Personal relationships between established British and other corrosion workers are and have always been at least as cordial as those between workers in other branches of science. Official contacts, however, have so far been lacking and this may have been, to many internationally minded young men, a real discouragement to specialize in corrosion. If it becomes generally known that, through organized channels, opportunities for visits, exchanges and so forth in industry and the universities of different countries are as open in the corrosion field as they are in many others, many men just about to begin research may find a career in corrosion more attractive. Another advantage of official international contacts will be that personal and public welcomes to eminent foreign corrosion workers may be supplemented with a greater number of suitable public occasions

It seems appropriate, therefore, that in an article on the formation and aims of the new Corrosion Group, specific and grateful acknowledgment should be made of the example set by the formation in the United States of the National Association of Corrosion Engineers—the first English-speaking organization devoted to the study of corrosion.

The successful early years of NACE have now encouraged corrosion workers in Britain to remedy a similar defect in their scientific arrangements and to bring together people and papers in a general organization devoted solely to corrosion science and practice. The lead in this particular matter has been American. The writer is glad that this example has been followed as rapidly as Americans have on occasion followed Britain's lead! But imitation is not only "the sincerest form of flattery"; it is also, in this matter as so often in others, common sense.

I am greatly indebted to Dr. W. H. J. Vernon for supplying some of the information for this article and to Mr. F. L. LaQue for suggesting I should write it.

A Technique for Salvaging Pipe Under Street Crossings*

By BUFORD P. LEDBETTER* and HUGH WILBANKS, JR.**

Abstract

A description is given of a method of removing 750 feet of 6-inch and 8-inch wrapped steel gas main from beneath street crossings without cutting the street. A burner placed in one end of pipe under streets heated it to the flow point of the coal tar enamel coating when, with a winch line, the pipe was pulled out of its felt wrapper like a tamale slid out of its husk, using the melted coal tar enamel as a lubricant.

This procedure permitted recovery of pipe which could not have been saved economically otherwise. Details of technique are given and operations are illustrated with photographs.

Inspection of coating on removed pipe indicates application of coal tar enamel in excess of 3/32-inch in the type of soil encountered would be of very little value.

A SPECIAL TECHNIQUE has been developed for removing coated pipe from under paved streets and other inaccessible places, using the coating as a means for removal. Pipe shortage and economy made it necessary to remove an unused gas main for use in rehabilitation work. The line to be removed consisted of 4800 feet of 6-inch and 8-inch wrapped steel pipe and the problem faced was certain loss of approximately 750 feet which lay under street crossing, driveways, etc. As is always the case, economics became of prime importance and it was determined that it was not economically feasible to cut the streets to remove this pipe since the cost of street cuts and repairs would exceed the cost of new pipe. As a result, a special removal technique was developed in the Cathodic Protection Section of the Gas Division of the City of Corpus Christi, Texas. This technique was viewed somewhat skeptically by all concerned until proved a success.

Briefly, the operation consisted of removing the pipe on each side of the street crossing and leaving the ditch open. A burner was placed in one end of the pipe and a winch line tied to the other end. When the pipe was heated sufficiently to raise the temperature of the coal tar enamel to its flowing point, the pipe was pulled out of its felt wrapper, using the melted coal tar enamel as a lubricant between the outer asbestos felt wrapping and the pipe.

Detailed plans were prepared showing the 4800 feet of main to be removed, including the sections which lay under streets and lawns. A test run was made on a 26-foot section of 6-inch pipe which ran under a sidewalk and private driveway and this proved to be an extremely simple and fast operation. However, more difficulty was encountered in pulling long sections (75 feet-85 feet) of 8-inch and the following procedure was used. The coating was removed from the short section protruding from the ditch wall on both sides of the crossing to reduce smoke and fumes while the pipe was being heated.

Heat was applied to the up-wind end of the pipe in order to get proper draft to carry the heat through the section of line (a vent was used when wind conditions prevented proper draft). An Aeroil product No. 11K kerosene burner was used as the heating unit and the flame was directed into the end of the line. (See Figures 1 and 2.)

Figure 1

Figure 2

*Presented at a meeting of South Central Region, National Association of Corrosion Engineers, Corpus Christi, Texas, October 18-19, 1951 under the title "Operation Tamale."

*Superintendent of the Gas Department, City of Corpus Christi.
**City Gas Engineer, Gas Department, City of Corpus Christi.

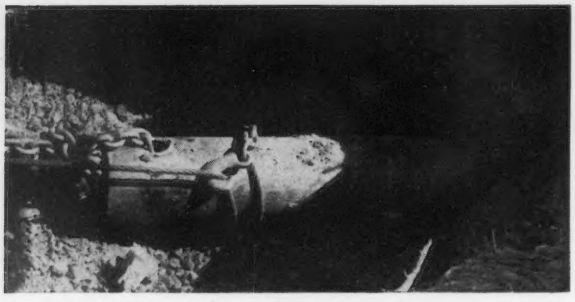

Figure 3

Figure 4

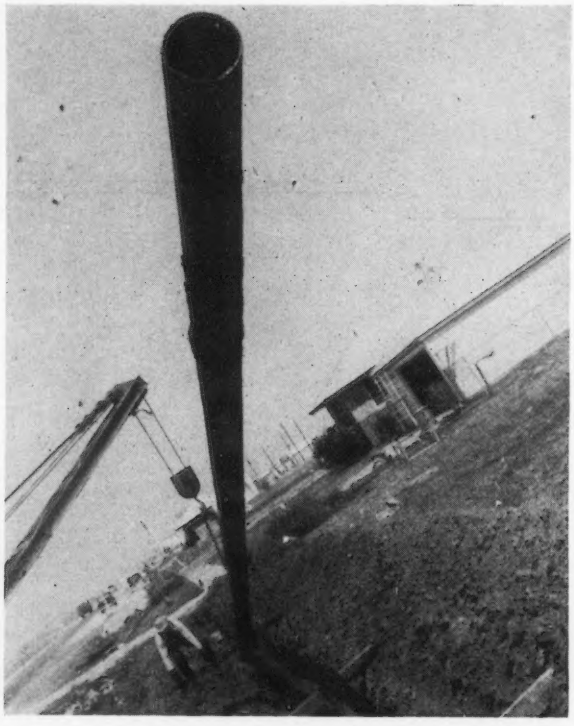

Figure 5

A winch line was attached to the opposite end of the pipe and put under tension as shown in Figures 3 and 4. The coating was checked periodically at this end, because it was the low temperature point. When the enamel under the felt became fluid (above the melting point 200 degrees F) and below the application temperature (325-375 degrees F) the pull began. The average heating time was 40 minutes on a 75-foot section of 6-inch standard pipe and 70 minutes average on a similar section of 8-inch. It should be pointed out that when heating difficulties arise, the heating time can be reduced by about one-third by applying heat to both ends. In doing this, heat should be applied first to the end where the winch line is attached and secondly to the opposite end to prevent the burner from being in the way when the removal begins. It should also be noted that in pulling some of these long sections, the aid of an additional prime mover was needed to start the pipe moving. No difficulty was encountered at any time in keeping the pipe moving after it had started.

By this method it is possible to recover 75 feet of 8-inch pipe with a maximum of 10 man-hours expended, which includes time for backfilling under the streets after the pipe has been removed. Figure 5 shows one of the recovered 75-foot sections of 8-inch pipe. Backfilling was done by hand, using a small diameter pipe with an enlarged tamp on the end to push the fill under the street. It is believed this provides a sufficient volume of dirt to prevent street failure.

Removal of the remainder of this 4800-foot section of 6-inch and 8-inch main afforded an excellent study of the effects of soil action and coating deformation on coal tar pipe line enamel and also on the value of cathodic protection. The line had been in service four years in a black gumbo soil containing a good percentage of bentonite (soil resistance 400 to 800 ohm centimeters). The first two years after this line was laid the moisture content of the soil was normal. Since that time there has been an abnormal drought with practically no precipitation and as a result large cracks have formed in the ground, some measuring six inches wide at ground surface. All pipe making up this line was mill wrapped. The application consisted of cleaning, priming, flood coating with 3/32-inch minimum coating of coal tar enamel, followed by 15-pound asbestos felt and Kraft paper. Field joints were made with the same enamel as that used in mill wrapping. Where the coating thickness was at the 3/32-inch level or slightly less, deformation was much less noticeable than where the coating thickness was heavier. It should be noted here that soil action in this area repeatedly breaks 4-inch Class 150 cast iron pipe. Coating deformation shown in Figure 6 was found to be most severe on the bottom of the pipe in the first section of line laid. This section consisted of 850 feet of 6-inch pipe which was laid during a dry season and no attempt was made to remove clods from the trench. The remainder of the ditch was cleaned and thus very little deformation was found. Some field joints showed more deformation than on the mill wrapping and this was attributed to excessive coating thickness. No failure of the coating from soil action occurred because the minimum coating thickness found was 2/32-inch or above, in the depressed areas. This would indicate that an application of coal tar enamel in excess of 3/32-inch would be of little added value in this type soil.

This gas main was well protected due to an excel-

lent coating job, proper handling during laying and application of magnesium anodes. A potential of —.85 volts or above was maintained at all times with low current requirement. It was evident that this line, following normal precaution during removal, had the same value when removed as when laid four years ago. In removing the line the dirt was loosened from the top and edges of the pipe following the ditching operation, Figure 7.

Special care was taken not to allow the ditcher buckets to touch the pipe coating. Close inspection revealed no corrosion at any point on this line. It is noteworthy that a bare steel main laid in the same type soil experienced several penetrations during a four year period, the first penetrations showing within eighteen months to two years after laying. Following checks made on the coating and steel, this salvaged line is expected to be re-laid, after patching the few holidays found, and will be considered equal in value to new coated line. The only loss encountered will be that which occurs in cutting and beveling.

In conclusion, in performing an "Operation Tamale" the following precautions should be considered:

1. As soon as the pipe starts to move, the burner should be cut off and the hole entrance covered with dirt fill. The same applies to the opposite end when the pipe is pulled completely out. This is done to prevent a flash fire from the coal tar fumes.
2. Caution should be taken to prevent overheating which removes the lubricating qualities of the coating leaving an ash residue.
3. The ends of the pipe should be cleaned of coating up to the ditch wall to prevent excessive fumes while heating and possible danger from fire.
4. A fire extinguisher should be kept on location at all times as shown in Figure 1. No fires were encountered during "Operation Tamale"; however, the possibility was not overlooked.
5. It is essential that proper draft be maintained at all times in order to get more even heating and to prevent possible flash back. A vent may be necessary when wind conditions are not correct.

Figure 6

Figure 7

The Corrosion of Copper and of Metals In Bi-Metallic Systems*

By GEORGE RICHARD HILL

THE KINETICS of the initial corrosion of copper in aerated salt solutions is under investigation in the Fuel Technology Department at the University of Utah under the sponsorship of the Office of Naval Research. The work has given an insight into the formation of the initial film of corrosion products produced when clean copper is placed in a corrosive medium. The technique used in determining the corrosion rate as a function of temperature, pH, salt concentration and oxygen pressure has been to allow a cleaned sample of electrolytic copper plate to be oxidized for periods of from five seconds to ten minutes in a controlled environment and then to reduce the film of corrosion products at a known potential and current density, measuring the time required to reduce the surface film to metallic copper. The details of the method used and the results obtained have been reported elsewhere.[1]

Some of the results of these studies and of similar work[2] are pertinent to a discussion of corrosion in bi-metallic systems. One result is the determination of the initial rate of corrosion of copper under these conditions. Copper is traditionally considered to be a metal which corrodes very slightly; yet these studies have shown that if it were not for the inert nature of the corrosion film formed on the surface, copper would corrode at a rate of 1600 mg/dm²/day or 0.26 inch per year.

The effect of the formation of a film of corrosion products on the rate of corrosion of copper is shown in Figure 1. Notice in this plot of film thickness versus the time of corrosion the very rapid initial rate compared with the very slow rate at which the metal corrodes when a protective film seals the surface from further attack.

Pipes, sheets and structural members made of copper, iron, steel, zinc, magnesium and the other metals and alloys used industrially frequently owe their prolonged existence to the formation of protective films. The natural films include oxides, carbonates, sulfates and basic salts in the forms of rust, boiler scale and the like. Without the protection of these intimately associated surface coatings the structures containing metal would need replacing very frequently.

It has been demonstrated[3,4,5,6,7] that most corrosion is electrochemical in character, i.e., the anodic and cathodic reactions occur at different points on the metal surface. In any system undergoing electrochemical corrosion, whether it be a single metal or a bi-metallic couple, closed electrical paths are involved. Areas at which the metal is becoming positive ions, or a compound containing these ions, are called anodes and areas where reduction is taking place are called cathodes. The rate of corrosion is regulated by the slowest reaction in the circuit—generally the one involving the highest resistance.

One reason surface films are protective is that corrosion products serve as high resistances in the corrosion cell circuits. The coupling of a metal to one dissimilar to it, for example iron to copper, provides an alternate path for the corrosion current and offsets the protecting effect of the high resistance film of corrosion products.

The electrical circuit for a system consisting of iron and copper and of water containing dissolved salts and oxygen can be seen schematically in Figure 2.

The corrosion circuit involves two chemical reactions, electron flow and ion migration. At the iron-water interface a chemical reaction, the formation of ferrous iron, is occurring. The electrons lost by the iron are conducted electrically to the copper at whose surface the second chemical reaction occurs. This usually involves the reduction of oxygen and the formation of hydroxyl ions, although in acid solution hydrogen ion reduction is the predominant

GEORGE RICHARD HILL—Acting head of the University of Utah's Department of Fuel Technology, Mr. Hill's principal interests include research on the kinetics of initial corrosion processes, the characteristics of catalysts and the kinetics of combustion. With an AB from Brigham Young University 1942, Mr. Hill's PhD is from Cornell 1946. He has been with University of Utah since 1946. A member of Sigma Xi, American Chemical Society, he is vice-chairman of Salt Lake Section NACE.

Abstract

Results of experiments in the Fuel Technology Department of the University of Utah into the kinetics of the initial corrosion of copper in aerated salt solutions are given. These show the quick formation of a film inhibits corrosion of copper. Theoretical considerations involved in the corrosion of an iron-copper couple are explained.

★ Presented at a meeting of Western Region, National Association of Corrosion Engineers, Los Angeles, Cal., November 9, 1951.

reaction. Electrical balance for the system is maintained by the migration of ions in the solution—the ferrous and other positive ions moving toward the cathode and the hydroxide and other negative ions toward the iron anode.

Had the iron been the only metal in the system, the ferrous (and later ferric) ions would have been formed in the immediate vicinity of the hydroxide ions and a high resistance film of hydrated iron oxide would have formed on the surface of the iron. The detrimental effect of coupling copper to iron is the introduction of a surface on which the cathodic process (production of hydroxide from oxygen and water) can occur without the simultaneous formation of a protective film.

This disadvantage of coupling dissimilar metals is not the result of a change in the final equilibrium of the system but to an increase in the rate of attainment of equilibrium, in this case conversion of the iron to the oxide. The absolute voltage difference between the two metals in the electromotive series is generally of minor importance so far as the increase in corrosion rate is concerned. The property that is important is the facility with which the cathodic process takes place upon the surface of the non-corroding metal.

The processes which limit the rates of corrosion of single metals or of metal pairs can be visualized quite easily in terms of the closed path of the corrosion electrical circuit. The over-all rate of the process can be decreased by the following procedures:

a. Increase the resistance to electron flow between the metals. The easiest way to accomplish this for piping systems involving different metals is to couple them together with insulating unions, nipples, elbows, etc. so that electron flow between the metals is prevented. Corrosion due to the extra surface provided by the more noble metal will cease; the residual corrosion will be due to local action only.

b. Prevent the cathodic reaction, the reduction of oxygen or hydrogen ion on the more noble metal surface. This can be done by coating the noble metal (in general, copper) with an impervious coating, or by removing oxygen from the surrounding water (or soil) solution.

c. The solution surrounding the two metals contains dissolved salts whose ions must migrate to maintain electrical neutrality so that corrosion can proceed. Removing salts from the solution by the use of distilled water or of a non-ionizing solvent can decrease the rate of corrosion.

d. Prevent the chemical reaction at the anodic surface by covering the metal completely with an insulating, impervious coating. The cessation of corrosion by this means will occur because of the potential rise due to positive ions being formed without the simultaneous provision of a negative ion to neutralize the charge. A small hole through such a coating can be disastrous however, since ion migration can occur at this point, allowing the corrosion to proceed at a rapid rate. Pits and pin holes result very quickly under these conditions.

e. Provide an easier source of electrons than from the corroding metal. This can be done by adding a third metal like magnesium to the system or by providing an external emf. The current provided by the external source must exceed that which would have come from the corrosion process to stop the corrosion completely.

It is apparent that three of the most practical means for minimizing the corrosion due to connecting copper to iron are, a) the use of insulating couplings, b) the coating of the more noble metal (copper), or c) cathodic protection.

The change in the rate of corrosion of very pure iron which occurs as some copper is connected to it and the effect of the area of the copper surface on the rate can be schematically represented in Figure

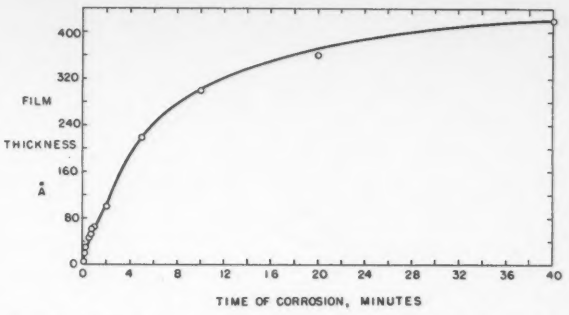

Figure 1—Variation in corrosion film thickness with time of corrosion.

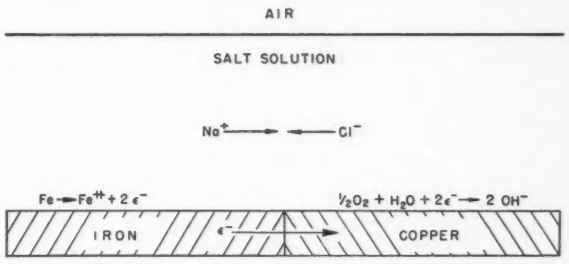

Figure 2—Corrosion of iron coupled to copper in salt solution.

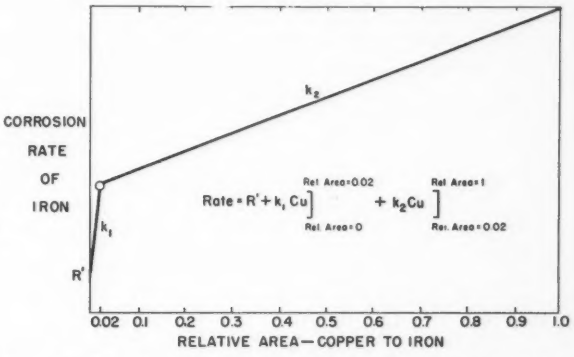
CORROSION RATE OF IRON
k2
k1
R'
Rate = R' + k1 Cu [Rel. Area=0.02 / Rel. Area=0] + k2Cu [Rel. Area=1 / Rel. Area=0.02]
0.02 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
RELATIVE AREA—COPPER TO IRON

Figure 3—The effect of varying copper area on the corrosion of iron.

3. (Curve representing corrosion rate versus relative area, copper to iron.) The normal rate of corrosion of iron is indicated by the positive intercept on the ordinate at zero copper. A very steep increase in rate occurs with the coupling of a small amount of copper to the iron. This rapid change in rate is due to a shift in the controlling mechanism in the reaction. Before coupling to the copper the corrosion is limited by the rate of depolarization of oxygen on the oxide coated iron surface. This is due largely to the resistance of the oxide film to electron migration and to atom and ion diffusion through it. After coupling, a new, more rapid rate occurs because the reduction of oxygen takes place more rapidly on the relatively clean non-corroding copper surface. In the event the iron already possessed definite areas acting as cathodes, the magnitude of the change due to coupling would be relatively small.[8]

One expects the rate of corrosion to increase in proportion to the total area of copper after this initial

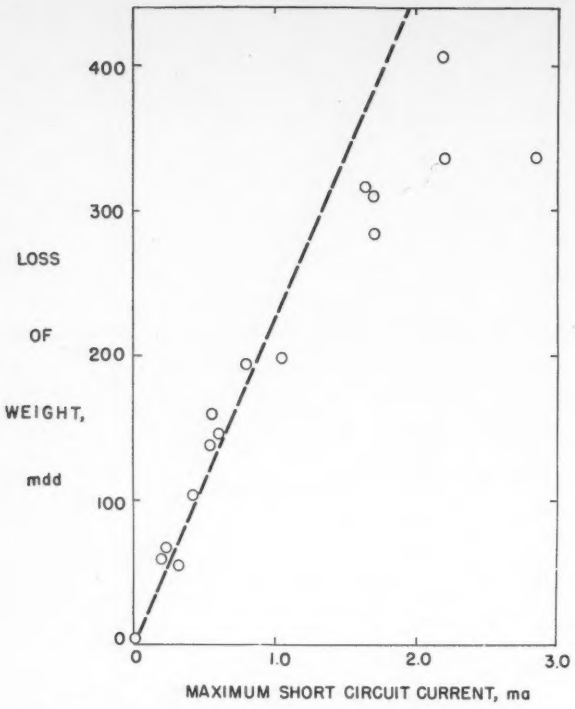

Figure 4—Relation between corrosion current and weight loss.

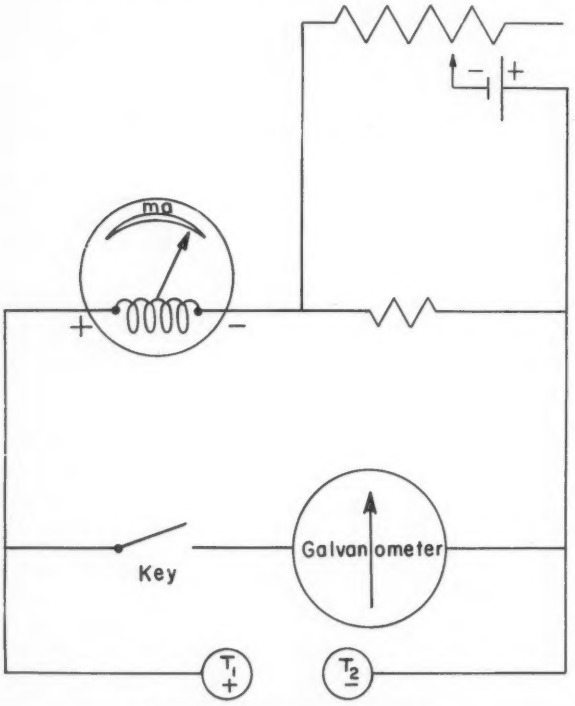

Figure 5—Zero resistance ammeter.

change has occurred. The expression for the behavior would be of the form,

$$\text{Rate} = R' + \begin{matrix}\text{Relative Area} = .02 \\ k_1\text{Cu} \\ \text{Relative Area} = 0\end{matrix} \quad \begin{matrix}\text{Relative Area} = 1 \\ + k_2\text{Cu} \\ \text{Relative Area} = .02\end{matrix}$$

where R′ is the rate of corrosion of the iron alone, k_1 is the large rate constant associated with the change in the corrosion mechanism and k_2 is the smaller proportionality constant for the increase in rate which accompanies increasing the amount of copper above the critical minimum. In such bi-metallic systems the corrosion is most frequently under cathodic control, i.e., the over-all rate increases with the area of the copper cathode. A surface coating on the copper to prevent oxygen from reaching it will be effective in proportion to the area covered. Pinholes or flaws in the coating will not seriously increase the corrosion (if they exceed .02 relative area) as they would in the reverse case of incomplete covering of the iron.

The magnitude of the corrosion problem in bi-metallic systems can be determined quite readily by separating the iron and copper portions and measuring the current flowing between them using a "zero resistance" method.[9] Denison and his co-workers[10,11,12] have correlated measured values of the maximum short circuit currents and the currents at corrosion potential with the loss of weight of low carbon steel and other metals in soils of various types. A plot of their data is given in Figure 4. It will be noted that the loss in weight of their steel samples is almost proportional to the corrosion current. Furthermore the total amount of corrosion is very close to that predicted from Faraday's Law calculation, as is indicated by the broken line in the figure.

Because of the close agreement between theory and experiment, it is reasonable to suggest that most metals in a bi-metallic system, where the corrosion is under cathodic control, will corrode at a rate directly proportional to the current flowing between the two parts of the system. Corrosion may exceed this amount if local action occurs; if the corrosion current decreases with time (which occurred in Dr. Denison's experiments in low resistivity soils) slightly less corrosion will occur than would be predicted. In any case the method will give a good first approximation to anticipated corrosion.

To calculate the weight loss of iron or steel pipes in such systems the following relationship applies:

$$\text{weight loss in mg per day} = i\ (\text{amperes}) \times 86{,}400\ \text{seconds} \times \frac{0.2983\ \text{mg Fe}}{\text{Coulomb}}$$

$$\approx 25 \times i\ (\text{milliamperes}).$$

If the corrosion is concentrated near the junction of the two metals in a one foot length of one inch iron pipe, the corrosion rate would be,

$$\text{Rate in mdd} \approx 10 \times i\ (\text{milliamperes}) \text{ or}$$
$$\text{Rate in ipy} \approx 1.83 \times 10^{-3} \times i\ (\text{milliamperes})$$

Short circuit currents can be measured by means of a "zero resistance" ammeter. A circuit for such an instrument is shown in Figure 5.[9] The use of a low resistance milliammeter in making the measurements is not suitable because this might alter the total current appreciably.

From the results of the measurements semi-quantitative predictions can be made regarding the anticipated effects of corrosion in bi-metallic systems. If

the economics warrant, and usually they do, the system can be modified by the methods described to minimize or eliminate the corrosion.

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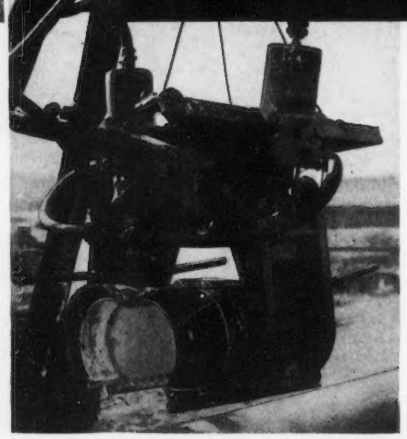

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Topic of the Month

Inner Coating a Corroded Gasoline Storage Tank With Concrete

By EDWARD H. TANDY*

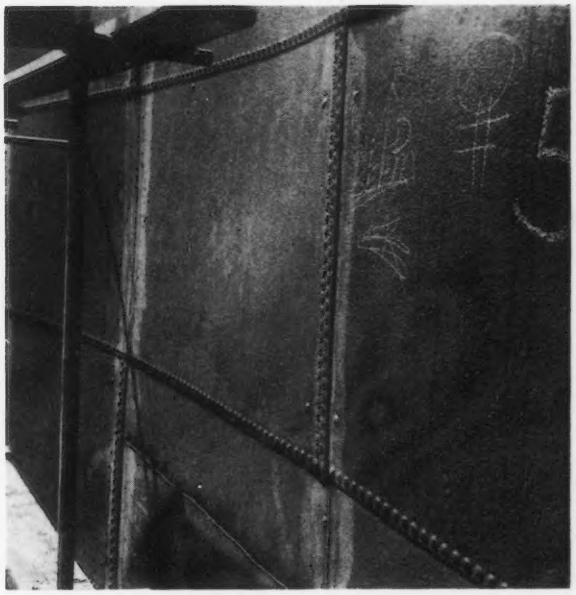

Figure 1—Condition of plate in most severely corroded areas.

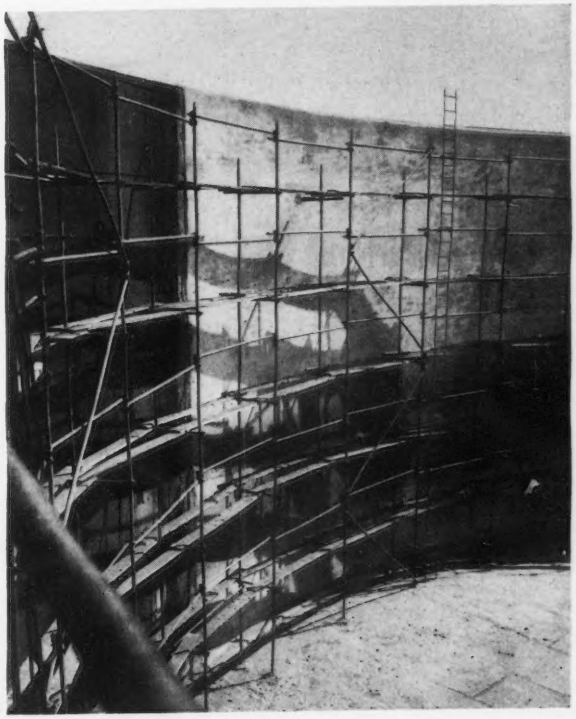

Figure 2—During installation of concrete lining.

THIS GASOLINE storage tank, 115 feet in diameter and 38 feet high, built in 1922 was equipped originally with a water seal roof. During its service four of the seven courses corroded to the minimum allowable thickness. It was decided to apply a concrete coating and to equip the tank with a floating roof.

Figure 1 shows the condition of the plate and the riveted joints in the most severely corroded areas. Edges of the joints were lap welded and rivet heads, which were almost completely corroded away, were seal welded on the inside.

Prior to applying the concrete, the shell was completely sand blasted and a 2-inch x 2-inch by 16-gauge galvanized wire mesh was installed over 3/16-inch vertical rods crimped and welded to the shell on 18-inch centers. A 1½-inch thickness of concrete was then blown over the mesh and the surface steel-troweled to provide a smooth surface for the floating roof shoes.

*Head Equipment Inspector, Standard Oil Company of California, El Segundo, Cal.

NACE News

H. L. O'Brien Is General Chairman of '53 Conference

H. L. O'Brien, product manager of Graver Tank & Mfg. Co., East Chicago, Ind., has been named general chairman of the National Association of Corrosion Engineers' 1953 Conference and Exhibition to be held at Chicago. The dates are March 16 through 20 and headquarters will be the Sherman Hotel. NACE President M. G. Fontana also announced H. W. Schmidt of Dow Chemical Company, Midland, Mich., had accepted the chairmanship of the technical program.

Carl B. Smith of Dearborn Chemical Co., Chicago, has accepted chairmanship of the exhibits committee.

These chairmen are to name members of their respective committees in the near future, including the local arrangements committee chairman and various sub-committees.

Other plans for the meeting are well under way. An inspection of the facilities of the Sherman Hotel by the officials responsible for the program and by A. B. Campbell, NACE executive secretary, indicates ample room for a large exhibit and good arrangements for meeting rooms for committees and technical sessions. Adequate hotel room accommodations at the Sherman and at nearby hotels is expected to be available.

North East Region Holds Corrosion Conference, Board Meeting, TP-6C Session

Northeast Region and Metropolitan New York Section held a one-day corrosion conference April 23 at 2 Park Ave., New York City. The program opened with a regional board meeting at 10 a.m., and a session of NACE Technical Practices Committee 6C on Protective Coatings for Resistance to Marine Corrosion.

At 1:30 p.m., H. H. Uhlig, head of the Massachusetts Institute of Technology Corrosion Laboratory spoke on "Corrosion—A Look Into the Future." Ted S. Zajac, chairman of the NACE Technical Practices Committee spoke at 2:15 p.m. on "NACE Technical Practices Committee Activities." J. E. Draley, corrosion specialist for Argonne National Laboratory, Atomic Energy Commission, Chicago spoke at 3 p.m. on "Some Corrosion Problems in the Atomic Energy Program."

The International Nickel Co. film "Corrosion in Action," was shown beginning at 3:45 p.m. after an introduction by T. P. May of the Inco Corrosion Engineering Section.

Metropolitan Section has scheduled a June 11 plant tour of the Socony Paint Products Company's new plant at Metuchen, N. J. The tour leaves Manhattan at 1 p.m.

A. D. Stafford

Allen D. Stafford, 51, president of Corrosion Engineering Company, Houston, who died April 6, 1952 at a Houston hospital following a heart attack, was buried at Birmingham, Alabama, his birthplace. In Houston since 1942, he was president of the Allen D. Stafford Distributing Co., and a director of the International Fidelity Insurance Company of Dallas. He is survived by his widow, Mrs. Margaret J. Stafford and a son, Edwin O., both of Houston.

He was a member of NACE and of Phi Gamma Delta.

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The 1953 annual NACE meeting will be held in Chicago in March.

NOMINATIONS FOR 1953 NACE AWARDS

Should Be Made Not Later Than July 1

The Procedure for the Selection of Persons to Receive the Willis Rodney Whitney and Frank Newman Speller Awards in 1953 as approved by the Board of Directors in Galveston, March 14, 1952, provides for nominations being made by a local section or by an individual member directly to the Chairman of a Region. All nominations should be accompanied by an appropriate statement of the basis of the proposal.

This Procedure requires that prior to July 1, 1952, the Regional Chairman shall forward to the Chairman of the Awards Committee all names proposed for awards, accompanied in each case by summaries of the reasons presented in support of each proposal, but with no indication of the number of duplicate nominations of any individual. The object of this latter provision is to insure that awards will be made on a basis of accomplishments and other qualifications rather than by any semblance of a popular vote.

The Procedure also requires that the NACE membership be notified of their privileges with regard to nominating candidates for these awards either by direct letter not later than May 1, 1952, or through publication in the May, 1952 issue of CORROSION. A direct letter is not contemplated; hence, this notice as it appears in this issue of CORROSION Magazine will serve as the notification to the NACE membership that nominations for these two awards may be made to their respective Regional Chairman not later than July 1, 1952. Reference to the Regional Division map on page iv and the Directory of Regional and Sectional Officers on pages iv and v of this issue will enable any member to obtain the name and mailing address of the regional chairman to whom his nominations should be sent.

Greater Boston Section Announces Committees

Committees for Greater Boston Section were named as follows at the section's March 20 meeting: Program and Arrangements, O. W. Robertson, Chairman; Charles G. Brown, Milton Stern and Edward C. Rue; Membership, James Dugan, chairman; A. Orman Fisher and Elmer A. Turner; Fellowship, Herbert W. Reinhard, chairman; Howard M. Kelley and Carlton L. Goodwin.

There were 39 members and guests present at the Smith House, Cambridge meeting to see one of the first showings of the new International Nickel Co. film "Corrosion in Action." Guest at the meeting was T. P. May of Inco, chairman of North East Region, who introduced the film with a commentary on the history and objectives of the production.

Members adopted by-laws as drafted by Manson Glover, chairman of the by-laws committee who was assisted by John Swift and Daniel Cushing. Section Chairman E. J. Titsworth reported splendid progress and enthusiasm in the organizational groundwork of the new section.

After June 1, 1952
NACE's Address Is
1061 M & M Bldg.
Houston 1, Texas

Canvass to Fix Program for South Central Region Meeting

South Central Region's trustees at a meeting held during the Galveston Conference in March were told by John E. Loeffler, program chairman for the region's scheduled October 1-3 meeting at New Orleans that the program will be determined from expressions of interest returned by association members. A canvass of opinion is being conducted. Mr. Loeffler further said T. P. May of The International Nickel Co., Inc., New York tentatively is scheduled to talk on corrosion in marine environments.

Other matters discussed at the first and second meetings of the trustees included:

A reminder was given sections to appoint or select trustees and alternates. Further it was decided terms of trustees should be two years and that the following schedule of new terms govern: January 1, 1953, Sabine-Neches, North Texas, Corpus Christi, Central Oklahoma and Teche; January 1, 1954, Tulsa, New Orleans-Baton Rouge, Houston, Shreveport and Permian Basin.

Proposed revisions of the by-laws were discussed and a draft of the revision is to be prepared by H. V. Beezley.

M. C. Fleming, chairman of the region was asked to write sections requesting they put terms of section officers on a calendar year basis.

Mr. Oliver Osborn was named to represent the region on the association's educational committee.

The following nominations for officers for 1953 were submitted by the nominating committee: H. E. Waldrip, chairman; Thomas S. Moffat, Jr., vice-chairman; H. V. Beezley, secretary-treasurer and Derk Holsteyn, regional director.

Materials Selection Key To Stress Corrosion Ills

Proper materials selection is a practical solution to the problem of stress corrosion cracking in steel tubes, S. E. Daughty of Carpenter Steel Company told 24 members and six guests of Sabine-Neches Section March 27. The regular meeting was held at Port Arthur. Mr. Daughty's topic was "Practical Aspects of Stress Corrosion Cracking in Austenitic Stainless Steel Tubes."

A report of activities relating to sections at the Galveston conference was presented during the business meeting.

Resin Tapes Evaluated

"Evaluation of Resin Tapes as Protective Coatings," by L. A. Johnson, field representative for Minnesota Mining and Manufacturing Co., St. Paul, Minn., was the principal topic at a scheduled April 3 meeting of Pittsburgh Section at Mellon Institute.

Casing Failures Discussed

"Oil and Gas Well Casing Failures," was the topic scheduled for discussion at the March 18 dinner meeting of Shreveport Section. E. H. Sullivan of United Gas Pipeline Co., was the featured speaker.

Industrial Wastes Talk Is Heard at Cincinnati

Arthur Caster, Waste Disposal Engineer, City of Cincinnati, will speak to Southwestern Ohio Section at a dinner meeting April 29 on "Industrial Waste." The meeting will begin at 6:30 p. m. at Shuller's Restaurant, 7769 Reading Road, Cincinnati.

M. G. Fontana, of Ohio State University and president of NACE, will address the section May 27 on "Recent Developments in Corrosion Resistant Metals and Alloys," at a meeting opening at 6:30 p, m. at Hotel Biltmore, Dayton, Ohio.

An interesting and thorough discussion of galvanic corrosion and related phenomena was given by Raymond B. Hoxeng of United States Steel Laboratories at the March 25 dinner meeting attended by 29 members and 19 guests.

Western New York

Western New York Section is scheduled to elect new officers at a May 15 dinner meeting to be held at Hotel Markeen, Buffalo. Dinner will begin at 6:30 p. m. The International Nickel Company motion picture "Corrosion in Action" will be shown.

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Predicting Corrosion Is Discussed at North Texas Meeting

A logical development resulting from the intense study of corrosion that has taken place during the last several years is a method for predicting corrosion. This development was considered in a talk by D. A. Shock, of Continental Oil Company, Ponca City, Okla., to members of North Texas Section at a dinner meeting April 7 at Fort Worth.

Mr. Shock pointed out that for years the accepted method of approach to corrosion problems has been to wait for development of equipment failure before considering preventive measures. This method led to costly shut-downs and loss of expensive equipment. Through the framework of the NACE, cooperative efforts by many companies of various industries have shifted the emphasis of investigative effort to anticipation of corrosion.

Fundamental data accumulated have made possible the sound and scientific prediction of corrosion in oil and gas wells. While Mr. Shock's data dealt with oil and gas wells only, the principles developed were said to apply equally well to other industries.

North Texas Section's next meeting will be September 8. The May 5 meeting held in Dallas was ladies' night.

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NACE MEETINGS

CALENDAR

May

1—Pittsburgh Section. Corrosion of Underground Structures by Stray Currents by Norman Peifer, Manufacturers Light and Heat Co.
5—Dallas Section. Ladies Night.
13—Houston Section. Studies of High Pressure Sweet Oil Corrosion by H. L. Bilhartz. Discussion by R. C. Buchan. A display of specimens is planned.
15—Detroit Section.
15—Western New York. Hotel Markeen, Buffalo, 6:30 p.m. dinner meeting. Election of officers. Inco movie "Corrosion in Action."
20—Chicago Section. Round table dis-
26—Tulsa Section. Round table discussion oil tankage corrosion, moderators Franklin T. Gardner, University of Tulsa and Ernest Johnson, Service Pipe Line Company. Micaelis Cafe.
cussion on general corrosion problems.
27—Southwestern Ohio. Recent Developments in Corrosion Resistant Metals and Alloys by Mars G. Fontana, Ohio State University. Hotel Biltmore, Dayton, Ohio.
Sabine-Neches Section. Social meeting at Orange, Texas. Date unannounced.

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Drill Stem Corrosion Surveyed at Meeting Of Houston Section

Members of Houston Section March 18 heard and discussed three papers relating to corrosion fatigue of drill stem collars and prevention of this fatigue by cathodic protection. The technical program followed a 45-minute tour of the Hughes Tool Company Research Laboratories at Houston.

The papers were: "Corrosion Fatigue in Drill Stem Members," by A. P. Farr of Hughes Tool Company; "Reducing the Corrosion Factor in Drill Stem Members' Failure by Cathodic Protection," by Stanley C. Moore of Drill Collar Service Co., Midland, Texas and "How a Magnesium Anode Ring Protects Metal" and "Magnesium in the Presence of Chlorine Solutions," by Oliver Osborn of Dow Chemical Company, Freeport, Texas.

H. L. Bilhartz is scheduled to address the section at its May meeting on "Sweet Oil Well Corrosion at High and Low Pressures."

Bill Brooks of Dow Chemical Co. is program chairman for 1952.

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Requests for copies of Corrosion addressed to Central Office, Houston, are filled (except when issues are exhausted) at the rate of 50 cents a copy for association members and 75 cents a copy for non-members.

Corpus Christi Section Installs New Officers

Officers were installed by Corpus Christi Section at a March 26 meeting. There were 13 members and six guests present.

Officers are John W. Nee, Briner Paint Mfg. Co., chairman; C. F. Ward, Magnolia Petroleum Corp., vice-chairman; Maurice N. Emery, Western Natural Gas Co., secretary-treasurer.

Tom Moffett, retiring chairman, reported on the South Central Region Trustees' meeting at Galveston. Members expressed their appreciation for the work of outgoing officers. The new chairman, Mr. Nee, outlined a suggested program for the year.

A general discussion session was held by Corpus Christi Section at its March 26 dinner meeting at Princess Louise Hotel, Corpus Christi. New officers were installed.

Aluminum in Petroleum Industry Is Topic at Tulsa Section Meeting

"Use of Aluminum in Petroleum Production and Processing," was the topic of an address scheduled by Ellis D. Verink, Jr. of Aluminum Company of America before the Tulsa Section. The meeting was announced for April 29 at the Michaelis Cafeteria.

A round table discussion on oil tankage corrosion moderated by Franklin T. Gardner, University of Tulsa, and E. Johnson of Service Pipe Line Company was the topic at a meeting to be held May 26.

Permian Basin Section Names New Officers

Permian Basin Section has elected officers as follows: Johnny H. Shelton, National Tank Company, chairman; Lamar F. Sudduth, Stanolind Oil and Gas Co., first vice-chairman; Jay D. Stafford, National Tank Company, second vice-chairman, all of Midland; William A. Hopwood, Tnemec Company, Odessa, secretary-treasurer; C. O. Bundrant, The Western Company, Midland, trustee.

"Tungsten" Will be Used

The designation "tungsten" will be retained in Corrosion in literature dealing with that metal in reference to "wolfram" the designation agreed to by an international commission in Europe some two years ago, it was decided at a meeting of the NACE Corrosion Abstract Committee at Galveston in March. Because it is customary to make terminology uniform in Corrosion, tungsten will be used in every instance where the metal is mentioned in published material in Corrosion or in other publications of NACE.

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Technical Committees of NACE are formed when sufficient interest is evidenced and after approval by the chairman of the Technical Practices Committee and the association's governing board.

New Magnesium Anode Developments Discussed

Sixty-five persons attending a March 19 dinner meeting of Los Angeles Section at Rodger Young Auditorium, Los Angeles heard Robert Featherly of Dow Chemical Company speak on "New Magnesium Anode Developments." A question and answer period followed his talk.

The new International Nickel Co. color motion picture "Corrosion in Action," was shown.

New section officers were installed as follows: K. T. Vangsnes, The Vanode Co., Pasadena, chairman; S. J. Artese, Shell Oil Co., Inc., Wilmington, vice-chairman and S. K. Gally, Southern California Gas Co., Los Angeles, secretary-treasurer.

Discussion Records Now Being Canvassed

More than 170 records of discussions or questions which were reported in writing to the NACE during and subsequent to the technical sessions at Galveston in March now are being processed at Central Office. Where discussions are fragmentary or notative, discussors will be requested by mail to supply the association with fully written remarks. These remarks are not restricted to length and pertinent illustrations and figures and tables are welcomed. Following receipt of written discussions, the collected discussions pertaining to each paper presented will be sent to authors for their comments. The remarks and comments then are reviewed by the editor of CORROSION. Publication at the same time as the paper to which they pertain is preferred, but when the paper is published prior to approval of the discussions, the latter are run as approved and keyed by reference to the appropriate paper.

Discussions and remarks pertinent to papers presented at Galveston still are being accepted. The association's policy is to consider for publication in its official journal "CORROSION" discussions of any of its technical material whenever the discussions are made available.

TP-5A Has New Officers

The following new officers have been named for Technical Practices Sub-Committee 5-A on Materials for Handling and Manufacturing Sulfuric Acid: C. L. Bulow, Bridgeport Brass Co., Bridgeport, Conn., chairman and W. A. Luce, The Duriron Company, Inc., Dayton, Ohio, vice-chairman.

TP-6B Adds L. L. Sline

L. L. Sline of Sline Industrial Painters, Houston, has been named co-chairman of Technical Practices Sub-Committee 6-B Protective Coatings for Resistance to Atmospheric Corrosion.

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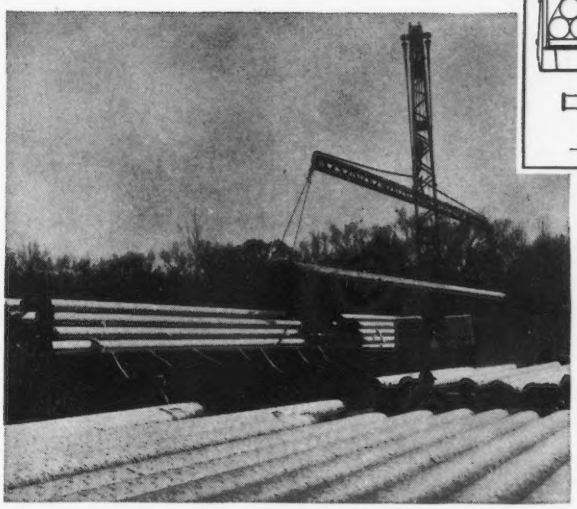
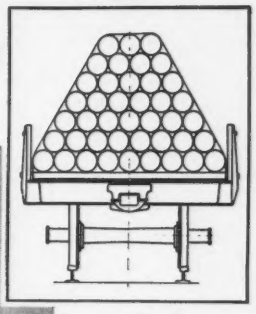
Nearly all technical papers presented at annual meetings of NACE are published in CORROSION after review by the Editorial Review Committee of the association.

Pyramid loading... careful handling of your pipe





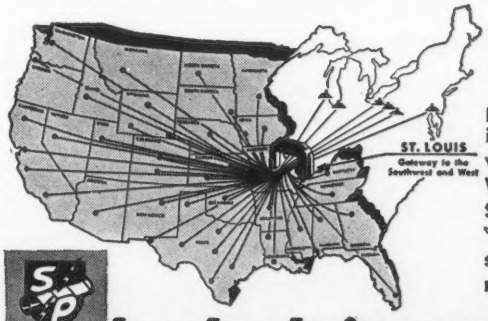
Cross-sectional drawing of pyramid loading.

Pyramid loading, an innovation of *standard pipeprotection inc.* largely eliminates the possibility of any damage to your pipe while enroute to you, because:—

1. **Tighter strapping than is possible in square loading can be used without damage to coating.**
2. **Should any load shifting occur, this tighter strapping results in the load shifting as a unit mass, thereby eliminating the shifting of one pipe on another.**
3. **The number of pipe lengths in contact with the sides and bottom of the car is substantially less than in square loading.**

While your pipe is in our plant it is handled with the greatest possible care through the use of cranes, skidways, spoolways, and electrically operated elevators.

During loading, your pipe is nested in pyramids, excelsior-padded, strapped into one unit and protected from dirt, dust, cinders, and weather by reinforced paper covering, to exceed the specifications of the Association of American Railroads.



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Decisions Made by TP-17 at Galveston

Several significant recommendations respecting the work of Technical Practices Committee 17 on Standardization of Procedures for Measuring Pipe Coating Conductance were developed during a meeting of the committee March 11 during the Galveston Conference. Chairman Wm. E. Huddleston reported as follows:

1. A field meeting of the committee is being planned at which members will actually measure coating conductance on pipe lines by the several methods that have been proposed.
2. Lyle Sheppard pointed out a temperature correction factor in measuring pipe coating conductance is needed.
3. Gordon Scott and several other committee members asserted pipe resistance calibration will be necessary in conection with coating conductance tests because pipe tables are not believed reliable.
4. L. G. Sharpe urged acceptance of common verbiage and definitions so all could discuss the matter on the same basis although varying methods of measurement might be preferred.
5. Mr. Scott proposed measurements be made on uncoated pipe line for purposes of comparison and that static potentials be observed in advance of conductance measurements.
6. E. R. Allen suggested a Pearson survey be conducted over the right-of-way of the test section to facilitate a check of the results of the conductance tests.
7. Agreement was reached on general specifications in preparing test sites for the field measurement tests.
8. The committee acknowledged receipt of blank data sheets from L. G. Sharpe for use in recording field data.
9. L. A. Hugo suggested following the meeting a part of the committee measure conductance of a section of mastic coated pipe line.

ASTM Committee Week Decisions Are Outlined

Activities of corrosion interest during American Society for Testing Materials 1952 Committee Week and Spring Meeting at Cleveland included:

Committee D-22 on Methods of Atmospheric Sampling and Analysis. Subcommittee II on Methods of sampling has formed six task groups including (f) Miscellaneous Materials (such as soil, vegetation, deposits, erosion and corrosion aspects). A proposed method for the continuous analysis and automatic recording of the sulfur dioxide content of air is being circulated to Subcommittee III.

Committee A-5 on Corrosion of Iron and Steel. The test sites at Key West were relocated and that at Sandy Hook was found to have been disturbed by army activities with the result that many of the wire and fence specimens were destroyed as well as a majority of the sheet specimens. Sheet specimen tests were discontinued at both sites because all remaining specimens have rust penetrations. A new specification for 1.25 oz. galvanized roofing sheets was set out to letter ballot. The committee also plans to draft a new specification for 7-wire strand overhead ground wire eliminating joints and specifying maximum and minimum footage per reel. The subcommittee on hardware is proposing a new exposure test of hardware specimens to include hot-dipped lead, hot-dipped aluminum, hot-dipped zinc, electroplated lead, electroplated zinc, and Sherardized, Galvanealed low-alloy steels.

Committee A-10 on Iron-Chromium-Nickel and Related Alloys. Subcommittee X has completed a Proposed Specification for Iron-Chromium and Iron-Chromium-Nickel Alloy Tubular Centrifugal Castings for General Applications. The committee will consider at its next meeting objections to the use of the term "corrosion-resisting," the suggestion having been made that the term "stainless" be substituted.

Committee B-7 on Light Metals and Alloys, Cast and Wrought. A proposed codification of alloys and temper designations has been developed, of which the committee is proposing publication of alloy designations and withholding temper designations. A number of new specifications to cover aluminum and aluminum alloy foil, foil for sandwich construction, welding wire, metallizing wire and misch metal are being developed. Subcommittee VIII on Atmospheric Exposure Tests announced that more than 1600 aluminum and magnesium specimens were now on exposure at New York City.

Committee B-8 on Electrodeposited Metallic Coatings. A photographic rating system of comparison of plating specimens is nearly ready for publication. A Recommended Practice for the Preparation of Copper and Copper-Base Alloys for Electroplating is out for approval. Work is under way on practices for malleable and gray iron, a task group on plating plastics has been organized and work on lead and lead alloys will be started soon. Subcommittee V on Supplementary Treatments of Metallic Coatings is planning a program to correlate accelerated tests with performance tests. Environments will include two outside exposures, a box exposure in an unheated warehouse and accelerated tests.

Pennsylvania ASM Meet Program Is Prepared

"Metals and Metallurgy of the Future" will be the keynote address by Dr. Zay Jeffries, retired vice-president of General Electric Company June 20 at the Eighth Biennial Pennsylvania Interchapter Meeting of the American Society for Metals. Hotel facilities at State College, Pa., where the June 20-21 meeting will be held, have been reserved en bloc for visitors. Reservations are being received by H. M. Davis, Division of Metallurgy, Pennsylvania State College, State College, Pa.

The program includes papers on current conservation problems in the metallurgical field by J. D. Morgan, Jr., B. S. Mesick and O. C. Ralston. Samuel Epstein and W. T. Lankford will preside over a symposium on relating laboratory tests to service performance featuring talks by Howard Scott, Frank Tatnall and I. V. Williams.

Saturday morning sessions will be devoted to steelmaking practice and metallurgical aspects of casting.

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ASTM 1953 Meeting Date Changed to June 29

The 1953 meeting date of American Society for Testing Materials has been changed to June 29-July 2 at the request of the Departments of Commerce and State and specifically of the United States National Commission of Pan American Railway Congress Association. The Eighth Pan American Railway Congress will be held at Washington June 12-25, 1953. American Institute of Electrical Engineers also cooperated in moving its 1953 meeting date to an earlier period in June. The ASTM and AIEE meetings will be held at Chalfonte-Haddon Hall, Atlantic City, N. J.

Competition for 1953-54 Fulbright Awards Set

Competition for 1953-54 awards under the Fulbright Act for university lecturing and post-doctoral research in East Asia and the Pacific, specifically at Australia, Burma, India, Japan, New Zealand, Pakistan, the Philippines and Thailand.

A special interim program for September 1952-June 1953 for Denmark, Iraq and Japan are tenable for the academic year beginning in September or October, 1952. A number of awards to become effective in October, 1952 are offered for Pakistan.

The 1953-54 competition for university lecturing and post-doctoral research in Europe and the Near East will be announced in June.

Applications and additional information may be obtained from Conference Board of Associated Research Councils Committee on International Exchange of Persons, 2101 Constitution Ave., Washington 25, D. C.

Instrumental Analysis Courses Set by MIT

Massachusetts Institute of Technology will conduct two one-week specialized training programs in instrumental analysis August 18-22 and 25-29. The courses are planned to enable chemists to study applications of new instrumental techniques and methods in the field of applied analytical chemistry. First program August 18-22 will be devoted to electrical methods and the second program to optical methods.

The special courses, will be conducted by David N. Hume and Lockhart B. Rogers.

All facilities of MIT will be open to summer session students. Living accommodations will be available at Alfred E. Burton House to those who request it with applications for admission. Requests for application forms and information should be addressed to Dr. Ernest H. Huntress, Director of Summer Session, Room 3-107, Massachusetts Institute of Technology, Cambridge 39, Mass.

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NACE will publish an annual directory of members of all organized committees of the association.

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The 1952 Annual Directory of Membership was published in the March, 1952 issue of CORROSION.

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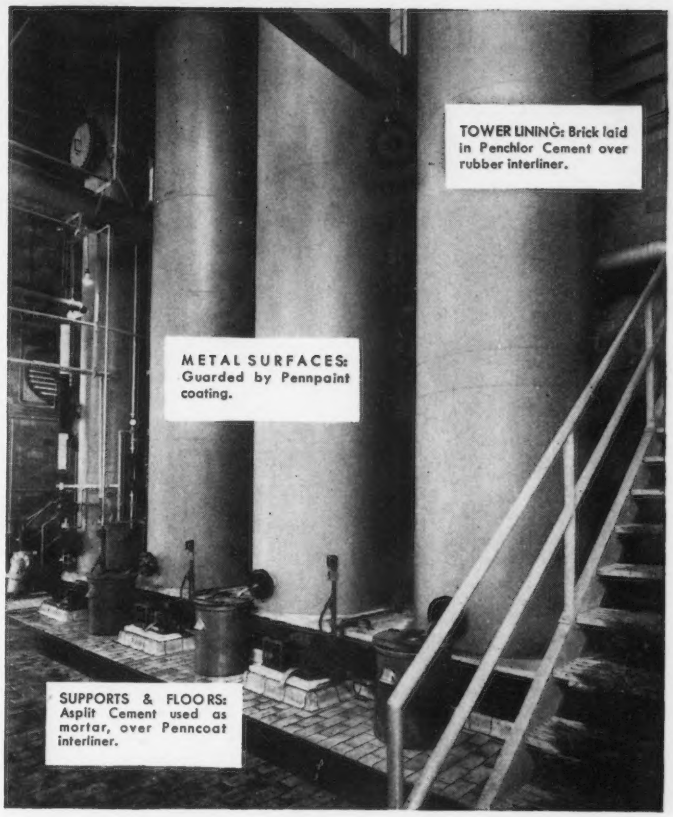
TOWER LINING: Brick laid in Penchlor Cement over rubber interliner.
METAL SURFACES: Guarded by Pennpaint coating.
SUPPORTS & FLOORS: Asplit Cement used as mortar, over Penncoat interliner.

For 13,200 hours . . . this room has handled H_2SO_4 saturated with chlorine

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Pearson and Godard Head Gordon Corrosion Conference; July 21-25 Program Is Outlined

The 1952 Gordon Research Conference on Corrosion, sponsored by the American Association for the Advancement of Science will be held at Colby Junior College, New London, New Hampshire from July 21 through July 25. Persons interested in attending are requested to send in application before May 15, stating institution or company with which connected and the type of work in which interested. Attendance at each conference is limited to 100. Requests for attendance or information should be addressed to W. George Parks, director, Department of Chemistry, University of Rhode Island, Kingston, R. I. Between June 15 and September 1, mail should be addressed to Mr. Parks at Colby Junior, College.

This year's conference on corrosion titled "A Critical Appraisal of Measuring Techniques," will have as its chairman J. M. Pearson and as its vice-chairman Hugh P. Godard.

The schedule will be as follows:

July 21

R. H. Brown. Measurements of Characteristic Potential Behavior of a Corroding Electrode as a Function of Applied Current or as a Function of Time.

Measurement of Properties of Surfaces.

T. P. May, Norman Hackerman. Measurements of Area by Adsorption of Gases.

D. C. Grahame. Measurement of Surface Roughness by Electrical Capacity.

July 22

Measurement of Properties of Surfaces.

Norman Hackerman. Radiotracer and Radioautographic Techniques.

Leroy Schultz. Optical and Electron-Optical Measurement of Surface Films.

Measurement of Changes in Properties of Corroding Metals.

Carl A. Zapffe or Frederic Landgraf. Fractographic Techniques and Tests for Hydrogen Embrittlement.

H. H. Uhlig. Measurements of Passivity and their Interpretation.

July 23

Measurement of Changes in Properties of Corroding Metals.

H. H. Liebhafski. Techniques for Studying the Oxidation of Metals at High Temperatures.

F. L. LaQue. Measurement of Damage by Cavitation, Impingement Attack and High Velocity Erosion.

S. Logan Kerr. Measurement of Cavitation Erosion and Correlation Between Laboratory and Field Observations.

Analysis of Corrosion Products and Corrosive Agents.

F. N. Alquist. Measurements of Hydrogen and Oxygen in Boiler Water.

July 24

Analysis of Corrosion Products and Corrosive Agents.

C. E. Imhoff. Analysis by X-Ray or Electron Diffraction Methods.

Armin H. Gropp. Polarographic Analysis of Corrosion Products and Measurement of Oxygen Consumption.

Statistical Treatment of Corrosion Data.

O. B. Ellis. Graphical Multiple Correlations.

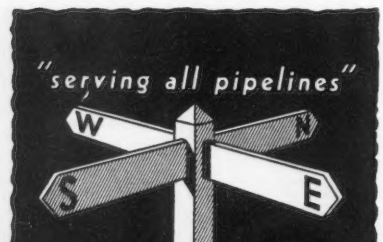
V. V. Kendall. Statistical Tools for Evaluation of Corrosion Measurements.

July 25

F. W. Fink, H. P. Godard. Summary of 1952 Corrosion Sessions.

Sessions are held daily from 9 a.m. to noon and from 7:30 p.m. to 10 p.m., except Friday when no evening session is held. Meetings are informal and no information revealed is published by the conference nor may anything discussed be published without permission of the author.

Accommodations are available to a limited number of women and children 12 years of age and older may be accommodated. Rooms are available at nearby hotels.



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Hot Dip Galvanizers Elect New Officers

Officers elected by the American Hot Dip Galvanizers Association, Inc., at its seventeenth annual meeting in Chicago March 24-25 were: D. M. Hayes of Wilcox, Crittenden & Co., Inc., Middletown, Conn., president; Frank W. Miller, Lehigh Structural Steel Co., Allentown, Pa., first vice-president; T. R. Gregory, Thomas Gregory Galvanizing Works, Maspeth, N. Y., second vice-president. Stuart J. Swensson was reelected secretary-treasurer.

German Standardization Committee Holds Meet

The Standardization Committee for Chemical Laboratory Equipment met at the Berlin, Germany, Technics Building and headquarters of the German Standardization Committee in Berlin December 12 and 13, 1951. The following proposals of the Working Committee for Laboratory Glass Apparatus were passed: German Industrial Standards 12 211, glass tubing and capillary tubing; 12 215, glass tube ends for tube connections; 12 257, reducers; 12 580, ball condensers; 12 591 Dimroth condensers; 12 602 Soxhlet apparatus.

Discussion about standards for ground joints, narrow and wide necked flat-bottomed flasks, Liebig condensers, volume measuring apparatus, mineral oil thermometers were held. A working committee for distillation and rectifying apparatus was set up.

Seven proposals for laboratory porcelain apparatus were made at a meeting of the Working Committee for Laboratory Porcelain Apparatus of which only a small part could be discussed. Discussions will continue between producers and consumers during 1952.

The Working Committee on General Laboratory Equipment received 13 proposals for laboratory metal apparatus which could be discussed only in part.

Next meetings of the committees are scheduled May 26-27, 1952, following the Achema X display.

Achema Yearbook Printed

The Achema Year Book 1951-52, published on behalf of Deutsche Gesellschaft for Chemisches Apparatewesen (Dechema) by Herbert Bretschneider, Frankfurt on Main, 1952, consists of 704 pages approximately quarto size. It lists the exhibits of the approximately 500 firms to be shown at the Dehema Dechema show to be held at Frankfurt May 18-25.

CORROSION MEETINGS

1952

May

11-14—AIChE (Regional Meeting) French Lick, Ind.

June

20-21—ASM Biennial Pennsylvania Interchapter Meeting, State College, Pa.

23—ASTM 50th Anniversary Meeting, New York, N. Y.

Sept.

4-6—AIChE (Regional Meeting) Chicago, Ill.

8-12—Instrument Society of America. Cleveland, Ohio.

Dec.

7-10—AIChE, Annual Meeting. Cleveland, Ohio.

1953

Mar.

2-6—ASTM Spring Meeting and Committee Week. Detroit, Mich.

June

29-July 2—ASTM Annual Meeting. Atlantic City, N. J.

Sept.

21-25—Instrument Society of America. Chicago, Ill.

Corrosion by Water Papers Are Published In Belgian Magazine

A copy of the Bulletin du Centre Belge D'Etude et de Documentation Des Eaux, No. 11, a quarterly magazine published at 2, rue Armand Stevart, Liege, has been received at Central office. Price is 75 francs per copy. Contents include a resume of The Hyrogeological Conditions Existing in the Low Countries and a report on the Corrosivity of Subterranean Water by W. F. J. M. Krul, Professor of the Polytechnic University of Delft, the complete text of which will be included in Bulletin No. 12; Corrosion in Boilers by R. Rath, Chief of Division Laboratories, Department of Heat and Electricity of France.

Resume of Corrosion of Iron by Fresh and Salt Water by George Chaudron, Professor of the Sorbonne and Director of the Laboratory of Chemical Treatment of Vitry, National Scientific Research Center; A Case of Corrosion of Cement Asbestos Pipe by Dr. H. Boorsma, Chief of the Chemical and Bacteriological Section of the State Institute for Sewage and Potable Water, La Haye; The Corrosion of Boiler Tubes, by Dr. E. W. F. Gillham and R. Ll. Rees, Chief Engineers' Department, British Electricity Authority, London; Forms of Corrosion Found in Steam Generating Plants by R. T. Hanlon, National Aluminate Corp., Chicago.

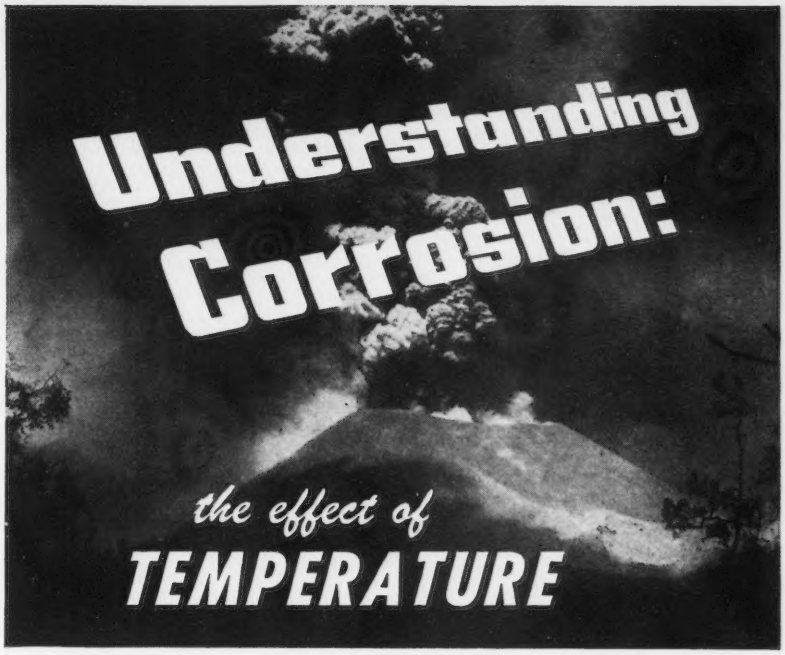
Resume of Some Results of Recent Work Undertaken by the Belgian Commission for Studying Protection against Corrosion, by M. D. Bermane, chemical engineer in charge of research of the commission, to be published in Bulletin No. 12; Resume of Some Aspects of Damp Blast Furnace Dust, by M. Moray, Engineer; Cathodic Protection Methods, by Kirk H. Logan, Research Engineer, Cast Iron Pipe Research Association, Washington.

Reduction of Corrosion in Water Distribution Systems, by Edward S. Hopkins, Bureau of Water Supply, Baltimore, Md.; Problems Involved in Using Chromates as Inhibitors in Water Circulating Systems, by Leo Cavallero and Antonio Indelli, from the General Chemical Institute of the University of Ferrara, Italy; Corrosion Problems in the Sugar Industry by R. Degrez, Inspector of Service and Iron Repairs, Tirlemontoise Sugar Refinery; Resume of Difficulties Caused by Corrosion by Wash Water in the Textile Industry, by M. U. Gombault, Department of Research and Control, of the Fabelta Corporation.

Moving Potable Water Containing Chlorine in Iron Pipe by O. L. Bihet, Chief Engineer, attached to the Department for the Meuse Pipe Foundries and H. L. Goldstein, engineer, Chief of Laboratory Service; Corrosion by Water, by Thomas H. Wiggin; Biological Aspects of Rust and Deposits in Piping, by Georges Van Benedin, attached to C.B.D.E.;

Microanalysts of Rust, by Jean Verbestel, Chemical Engineer and Armand Berger, Chemical Engineer, attached to CBEDE and Jaques Pirotte, Chemical Engineer attached to the Ministry of National Defense.

The Center also has issued an index to material published in 1948-50 inclusive.



Temperature exerts a large influence as a determinant of the corrosion rate of metal, with the nature of the metal and its environment, and the degree of temperature and duration of exposure operating as governing factors. It does so primarily by influencing the variables that determine the supply of dissolved oxygen at the metal surface. In closed water systems from which oxygen cannot escape, weight loss approximately *doubles* for every 60°F. rise in temperature. In open systems, despite a decrease in oxygen concentration, the corrosion rate likewise increases rapidly with temperature because of the speed-up of oxygen transfer to the metal, the maximum being reached at about 175°F. and decreasing thereafter to practically zero at the boiling point. In acid solutions, temperature rise also markedly accelerates corrosion while in alkali solutions, on the other hand, a comparable increase generally has a retarding effect, with the concentration of the alkali a determining factor.

Among other effects are greater localization of corrosion as temperature raises electrical conductivity of electrolytes, increased pitting as hotter metal becomes anodic to cooler, and less natural protection as temperature alters physical nature of corrosion products — effects that further establish temperature as a factor to be thoroughly explored in assessing any corrosion problem.

For metal serving at elevated temperatures Dampney coatings have long provided uniquely successful protection . . . whether under wet heat as in boilers and steam turbines (Apexior Number 1) or dry heat to 1600°F. (Dampney silicones, ceramics). Other Dampney materials (vinyls, chlorinated rubber, asphaltums) serve admirably at more moderate temperatures. Let us tell you more about these materials and the possibilities they offer in terms of your own corrosion control needs.

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One Step Determination Of Copper in Steel Possible by Method

A rapid, one-step method for determining the amount of copper in alloy steel has been developed by J. L. Hague and H. A. Bright of the National Bureau of Standards, and has been publicized in Technical Report 1661. Many high strength structural steels now being prepared for compliance to special or national emergency specifications are designed to utilize the alloy content of the scrap used in making the steel. This requires a rapid method of analysis.

One of the elements frequently used to alloy steel for increased strength and corrosion resistance is copper. The NBS method defined below has been developed to determine quickly the percentage of copper in a melt.

In the NBS method, the steel sample is first dissolved in dilute nitric acid. (For high-chromium steels, a mixture of nitric and hydrochloric acids is used.) A sulfuric-phosphoric-perchloric acid mixture is added, and the solution is evaporated until fumes of sulfuric acid are given off. The use of the sulfuric-phosphoric acid mixture provides for the complete solution of tungsten tool steels. The solution is then diluted and, after the addition of citric acid, is made slightly ammoniacal. The sodium salt of ethylenediamin-etetraacetic acid is added as a complexing reagent and sodium diethyldithiocarbamate is also added to form a copper complex. The complex is extracted with butyl acetate and the butyl acetate extract is washed with diluted sulfuric acid to stabilize the complex. The optical absorbancy of the copper diethyldithiocarbamate complex in the butyl acetate layer is measured in a colorimeter at 560 to 600 mu, and the amount of copper is read from a calibration curve or table. A single determination can be made in approximately 30 minutes and a set of eight determinations can be completed in about two hours.

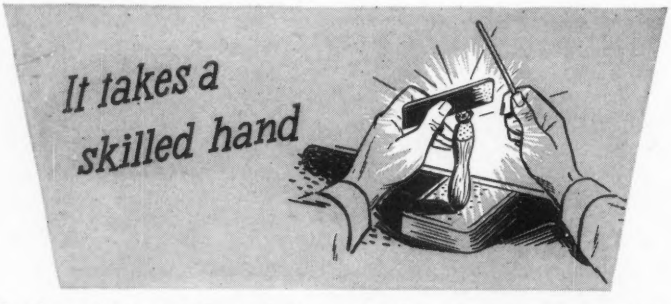
The reliability and accuracy of the method were checked by making a number of determinations on various NBS standard samples of iron and steel. An accuracy of the order of 0.001 percent of copper was indicated for samples containing less than 0.05 percent of the element. All average values obtained for samples containing from 0.05 to 0.25 percent of copper were within 0.005 percent of the certified value.

The fact that the nickel content of the sample does not interfere in the analysis constitutes an additional advantage of the new procedure, for many of the present-day copper-bearing steels also require the presence of nickel in the alloy. Stainless and corrosion-resisting steel, nickel-base casting alloys and tool steel can be analyzed for copper content by the NBS method as easily as carbon steel.

For further details, see Photometric Determination of Copper in Iron and Steel with Diethyldithiocarbamate, by John L. Hague, Eric D. Brown, and Harry A. Bright, *J. Research NBS*, **47**, 380 (1951) RP 2265.

Instrument Congress

The First International Instrument Congress and Exposition will be held September 14-24, 1954, at Philadelphia. Sessions will be held at the Commercial Museum and Convention Hall. This congress, at which foreign manufacturers of instruments will be invited to display their products, is expected to attract a world-wide audience, according to Richard Rimbach, managing director. The congress will mark the tenth anniversary of the founding of the Instrument Society of America.



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BOOK REVIEWS

Korrosionstabellen Metallischer Werkstoffe. By Franz Ritter. (In German) 283 pages, 6½ x 8½ inches. Cloth. (1952) Springer-Verlag, Molkerbastei 5, Vienna, Austria. Per Copy . . . $8.20.

Principal content of this book useful to the corrosion worker is 209 pages of tables in which the corrosion resistance of materials is related to alphabetically arranged corrosive agents. Data are given in weight losses of grams per square meter per day and in penetration values of millimeters per year. The data tabulated are derived from 991 literature references which are listed in a reference section.

The book includes a materials catalog in which the German, U. S. and British names of metals are tabulated against their analysis. The catalog covers metals from aluminum through zinc and precious metals.

Supplementary tables covering 18 pages give recent data on attacks by corrosives.

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Textbook of Electrochemistry, Volume II. By G. Kortum and J. O'M Bockris. 530 pages plus xiii. 6¼ x 9⅜ inches, cloth bound. Elsevier Publishing Co. 402 Lovett Boulevard, Houston, Tex. Per copy . . . $10.

This volume II (Vol. I reviewed in *Corrosion*, **7**, No. 11, Page 16 News Section, November, 1951) of the textbook by Kortum, professor of physical chemistry at Tubingen University and Brockris, lecturer in physical chemistry at the Imperial College of Science and Technology, University of London, begins with Chapter X. It contains the subject index. Chapter headings are Electrical Phenomena at Interfaces, Irreversible Electrode Processes, Electrochemistry of Gases, Experimental Methods of Electrochemistry, Tables of Certain Physico-Chemical Properties.

The tables are divided into four principal sets: 1. Universal physical constants and ratios. 2. Data concerning physical properties of chemical materials, e.g., refractivity, dipole moment. 3. Functions concerned in the physical chemistry of electrolytes, e.g., conductance, activity coefficients. 4. Data concerned with electrode processes, e.g., standard and redox electrode potentials and data on overpotential. These tables occupy 152 pages of the book. Problems related to the chapters of the book are in numerical order in a section on examples.

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Proceedings of the Second Meeting of the International Committee of Electrochemical Thermodynamics and Kinetics. 406 pages, 6¾ x 9⅜ inches, cloth. Libreria Editrice Politecnica Cesare Tamburini, via G. Pascoli, 55, Milano, Italya. Per copy, lire . . . 3800.

The International Committee of Electrochemical Thermodynamics and Kinetics (or CITCE, abbreviation of the French name of the organization) was created at a gathering of electrochemists which took place at the University of Brussels, Belgium, in March 1949. A second meeting was held at Pallanza,

(Continued on Page 11)

Book Reviews—

(Continued from Page 10)

Varenna and at the Politecnico of Milan, Italy, in September 1950. A third meeting was held at the University of Bern, Switzerland, in August 1951. The fourth meeting is scheduled for September 1952 at the University of Cambridge, England. The program of work of the committee includes the systematic preparation and experimental verification of potential—pH diagrams for the various elements, their applications to electrochemical kinetics, to corrosion, to inorganic and analytical chemistry, etc. The committee is also vitally concerned with all problems of electrochemical nomenclature and definitions.

The proceedings of the second meeting, published by the Libreria Editrice Politecnica Cesare Tamburini of Milan, Italy, constitute an attractive volume of 406 pages. It contains several pages of informal photographs of the participants, a list of participants and authors, reports by the president and the secretary, forty scientific papers divided in six sections (electrochemical equilibria, electrochemical kinetics, corrosion, general and analytical chemistry, polarography, nomenclature and definitions) and an appendix containing a general report on the second meeting, a provisional set of rules for the committee and an index of authors and participants in the discussions.

Eleven countries were represented at the meeting: Belgium, Canada, France, Germany, Great Britain, Italy, Norway, Spain, Switzerland, The Netherlands, United States of America. A total of about forty committee members were in attendance and a number of delegates of Italian industrial firms and governmental organizations also attended the meetings.

Readers of CORROSION will be specially interested in the section on equilibria (potential-pH diagrams) and in that on corrosion which contains seven communications, although the other sections also contain articles with definite bearing on corrosion problems. The majority of the articles are in French, some in German and English. The volume gives an interesting cross-section of electrochemical research throughout the world. The emphasis on fundamentals, typical of the committee's program, should be an inspiration in corrosion research and this volume is therefore highly recommended to individuals and laboratories engaged in such research. Members of the NACE may obtain this volume with a discount of 20 percent (i.e. at a price of 4.80 dollars instead of 6.00 dollars or 3800 lire) by ordering either from the publisher (Cesare Tamburini, Via G. Pascoli, 55, Milan, Italy) or from the Secretary of the Committee (Dr. M. Pourbaix, University of Brussels, 50 Avenue Franklin D. Roosevelt, Brussels, Belgium).—Pierre Van Rysselberghe, Department of Chemistry, University of Oregon, Eugene, Oregon.

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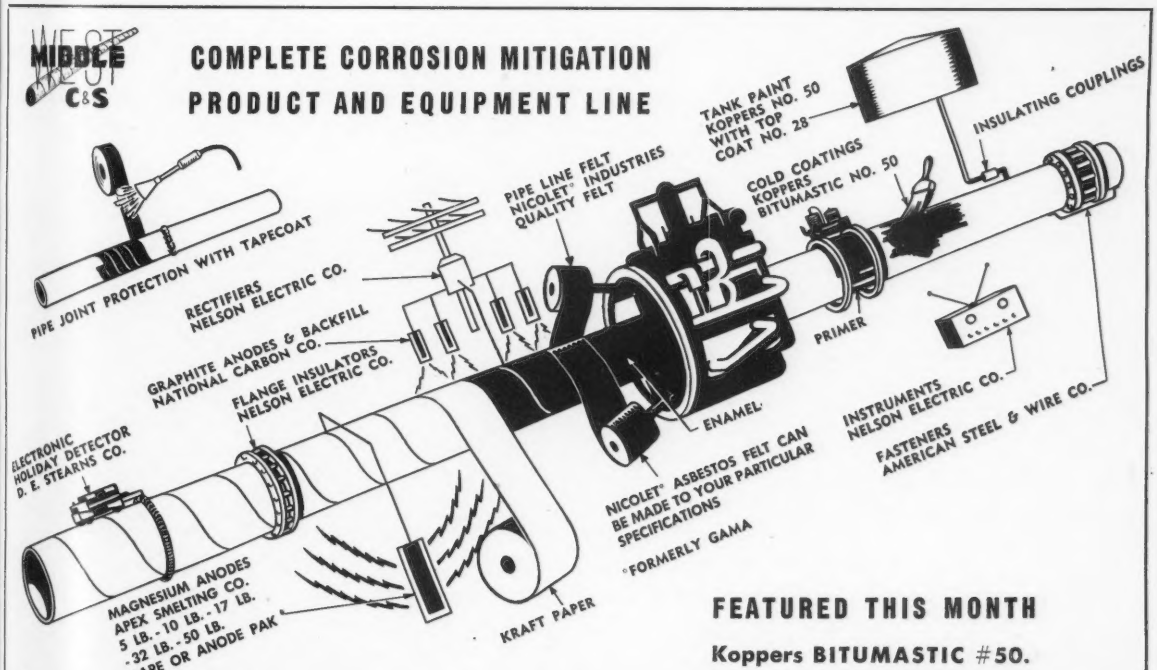
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Corrosion Problems

E. A. TICE, Editor

Corrosion Engineering Section, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

Submit questions and answers for this column in duplicate to the editor. All questions become property of NACE. Questions and Answers may or may not be published under this heading, and may at discretion, be answered by mail directly. Answers to questions are solicited. Authors of questions will remain anonymous to readers while authors of answers may remain anonymous if they request it.

QUESTION

No. 93—Can anyone cite cases of either stress corrosion or intergranular corrosion of silicon bronze in water at approximately 150° F. If so, can the cause of the attack be explained?

No. 94—(From one of our French Associates.) This problem is in reference to petroleum refining. Gasoline vapors, after leaving the top of the distillation towers, generally receive an ammonia injection to neutralize the free hydrochloric acid resulting from hydrolysis of $MgCl_2$ and $CaCl_2$ contained in the crude. This ammonia gas injection is generally regulated so that the water pH, after condensing mixed gasoline and water is as close to 7 as possible.

In spite of this injection, we have observed that in the temperature range of 100° C or somewhat higher, high corrosion rates for steel equipment prevail. Similarly, gasolines already neutralized with ammonia and insufficiently decanted after condensing, do sometimes, when reheated for rerunning show again the same corrosive properties in the above mentioned temperature range.

We should like to know whether other refineries using ammonia as a neutralizing agent have observed the same effect, and whether any research has been conducted to determine the efficiency of this process at various temperatures. Literature references connected with this problem would be most welcome.

No. 95—In the construction of a welded rectangular pot which will continuously contain molten caustic, which of the nickel bearing steels will prove the most economical?

ANSWER

In considering the 8½%, the 5% and the 3½% nickel steels alone and their relative resistance to attack by the molten caustic soda based upon weight loss corrosion rates, the higher the nickel content the greater the resistance. However, it does not follow that an 8½% nickel steel, for example, would be a practical choice. This steel probably would fail by stress corrosion cracking unless properly stress relieved and its rate of corrosion undoubtedly would be too high to permit the attainment of a satisfactory service life. We would expect similar situations to prevail for the 5% and the 3½% nickel steel. Corrosion rates of the order of ¼-inch penetration per year or greater would probably exist.

In an effort to provide some useful information of practical value, we would suggest consideration of a low alloyed cast iron, ductible cast iron, nickel or Inconel.

In the case of a low alloyed cast iron, the suggestion pertains to a composition which has been found to be useful for caustic pots, as are used in the alkali industry. Such a composition is shown below:

CAST IRON

	Comp. A	Comp. B
Total Carbon	3.50%	3.50%
Silicon	1.00	1.00
Manganese	0.75	0.50
Chromium	0.60	0.75
Nickel	1.50	3.00

The higher alloyed composition would be the preferred suggestion for optimum results.

In the case of ductile cast iron, sufficient service life experience is available with externally fired organic caustic fusion pots, to indicate this material should receive considerable attention.

In the case of nickel, the 0.02% carbon specification should be used to avoid graphitization. There is adequate experience available to show this material would be satisfactory.

In the case of Inconel, this alloy would be preferred over nickel if sulfur compounds were present in the caustic.—H. O. Teeple, International Nickel Co., New York.

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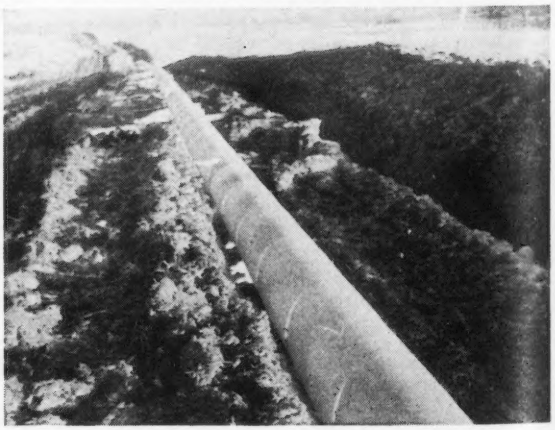

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STRAWDERMAN, HAROLD P., National Lead Company, 3113 East 26th Street, Los Angeles 23, Calif.

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Company.....

Address.....

City.....*State*.....

CHANGES OF ADDRESS

(Old Address Follows New In Parenthesis)

CALIFORNIA

HANSEN, TOLBERT L., 80 Wayne Court, Walnut Creek, Calif. (Trans-Arabian Pipe Line, Dhahran, Saudi, Arabia).

COLORADO

BROCK, JR., CHELSEY L., 7930 E. 16th Ave., Denver, Colorado (5818) Southridge, Houston 21, Tex.)

DISTRICT OF COLUMBIA

KEMP, JAMES T., 4522 Lowell St., N.W., Washington 16, D. C. (4452 Lowell St., N.W., Washington 16, D. C.)

GEORGIA

SMITH, WILLIAM A., William Armstrong Smith Co., P. O. Box 109, East Point, Georgia (Dixie Paint & Varnish Co., Inc., P. O. Box 256, Brunswick, Ga.)
WINTERS, B. W., Southeastern Pipe Line Co., 777 W. Peachtree St., N.E., Atlanta 3, Getorgia (718 Forsyth Bldg.)

ILLINOIS

BUNTING, WILLIAM E., 117 N. Reed St., Joliet, Illinois (Dowell Inc., 343 S. Dearborn, Rm. 1402, Chicago, Ill.)
JEKOT, CHESTER M., Lithcote Corporation, 333 West 40th Place Chicago 9, Illinois (Lithgow Corp.)
KINNEY, WAYNE L., Standard Oil Co., Products Pipe Line Dept., Box 5910-A, Chicago 80, Ill. (Electro Rust-Proofing Corp., 1229 W. Washington Blvd., Chicago 7, Ill.)

(Continued on Page 15)

Changes of Address—

(Continued from Page 14)

MANNING, PAUL D. V., Cen. Res. Lab. Lib., International Minerals & Chemical Corp., 5401 Harrison St., Skokie, Ill. (20 No. Wacker Drive, Chicago 6, Ill.)
QUINN, JOHN A., 2340 W. Moffet St., Chicago, Illinois (2907 Brazos, Houston, Tex.)

IOWA

BENSON, C. A., Northwestern Bell Telephone Co., 604 9th St. Des Moines, Iowa (224 South Fifth St., Minneapolis, Minn.)

KANSAS

BEGOLE, EDGAR RAY, 125 Clark St., Augusta, Kansas (1224 Henry).
CARTER, ANTHONY J., c/o W. J. Coppinger, Union National Bank Bldg., Wichita 2, Kansas (The Pure Oil Co., Box 551, Newark, Ohio).

LOUISIANA

LAENGER, RALPH E., Union Producing Co., Shreveport, La. (Box 711, Beeville, Texas).
NELSON, JR., LLOYD A., L. C. Rte., Box 555, Houma, La. (Freeport Sulphur Co., P. O. Drawer A, Freeport, Tex.)
NICKERSON, JAMES G., 7926 Sycamore St., New Orleans, La. (Union Tank & Supply Co., Box 114, Lafayette, La.)
VOGLER, GUS, Brance-Krachy Co., Inc., P. O. Box 264 Lafayette, Louisiana (Dowell Inc.)
WATERFIELD, JOSEPH H., United Gas Corp. New Iberia, La. (113 Harrison, Monroe, La.)

MARYLAND

BAUER, JEAN, 1900 Edgewood St., Baltimore 16, Maryland (The S. A. Williams Co., 1012 W. Lexington St.)
STREEP, SAMUEL C., 6236 Bellona Ave., Baltimore 12, Maryland (The Davison Chemical Corp.)

MISSOURI

ALLEN, JR., WILLIAM W., Owens-Corning Fiberglas Corp. 1006 Olive St., St. Louis, Missouri (2005 Continental Bldg.)
DOELLING, GEORGE L., 6332 Oleatha, St. Louis 9, Missouri (Wagner Electric Corp., 6400 Plymouth Ave.)
HUGHES, HOMER L., Missouri Natural Gas Co., P. O. Drawer 230, Farmington, Missouri (W. Columbia).
SHANAHAN, J. P., Shanahan Construction Co. & Assoc., Box 692, Waynesville, Missouri (5512 Natural Bridge St. Louis, Missouri).
WALSH, MARTIN P., Hartman-Hanks-Walsh Painting Co., 5078 Easton, St. Louis 13, Mo. (4903 Delmar Blvd.)
WEST, LEWIS H., Sohio Pipe Line Co., P. O. Drawer D-15, St. Louis 1, Mo. (1738-A Midland Bldg., Cleveland, Ohio.

NEBRASKA

WATTS, BRUCK B., K. W. Engineering Co., 216 So. 7th St., Lincoln, Nebraska (231 No. 11th St.)

NEW JERSEY

AYRES ALBERT L., New Jersey Bell Tel. Co., 540 Broad St., Rm. 1200, Newark 2, New Jersey (281 Washington St.)
HEINZERLING, ROBERT F., 145 Stonehouse Road, Glen Ridge, New Jersey (160 Terrace Ave., Hasbrouck Heights, N. J.)
HILTON, ROBERT W., 810 Berckman St., Plainfield, N. J. (1013 Rottkamp St., Valley Stream, Long Is., N. Y.)
VANDER VALK, CHRISTY J., 220 Roosevelt Ave., East Paterson, New Jersey (Lead Industries Assoc., 420 Lexington Ave., New York 17, N. Y.)
DE MAY, C. F., Columbia Gas System Service, 120 East 41st Street, New York 17, N. Y. (Columbia Engineering Corp.)
HECHT, JR., LEON M., 214 W. 92nd St., Apt. 2A, New York, N. Y. (Woodlawn Drive, Nashville, Tenn.)
GREBINAR, HERBERT L., Galvanite Corp., 40 West 29th St., New York 1, N. Y. (Chase Chemical Corp.)
HALL, MARVIN F., Ebasco Services, Inc., 2 Rector St., New York, N. Y. (Washington Gas Light Co., 100 H St., N.W., Washington 1, D. C.)
MONTEL, JOSEPH I., Hammond-Montel, Inc., 50 Church St., New York 7, N. Y. (175 27 Wexford Terrace, Jamaica 3, New York).
SEAMAN, EDWARD S., 5 Campus Place, Baldwin, New York (Edward S. Siegel).
WHITLEY, JR., B. J., Tennessee Gas Transmission Co., P. O. Box 98, Hamburg, New York (Box 65).
WYSSMANN, Otto W., 884 Parkhurst Blvd., Tonawanda, N. Y. 4051 So. Harlem Rd., Snyder 21, N. Y.)

OKLAHOMA

BRAND, JOHN W., Midwestern Engine & Equip. Co., Inc. Box 1886, Tulsa, Oklahoma (105 N. Boulder).
LAWLOR, E. W., Pittsburgh Coke & Chemical Co. 310 Thompson Bldg., Tulsa, Okla. (711 Thompson Bldg.)
SCHUELER, ROBERT C., 2200 S. Dewey, Bartlesville, Okla. (Celanese Corp. of America, Box 148, Bishop, Tex.)

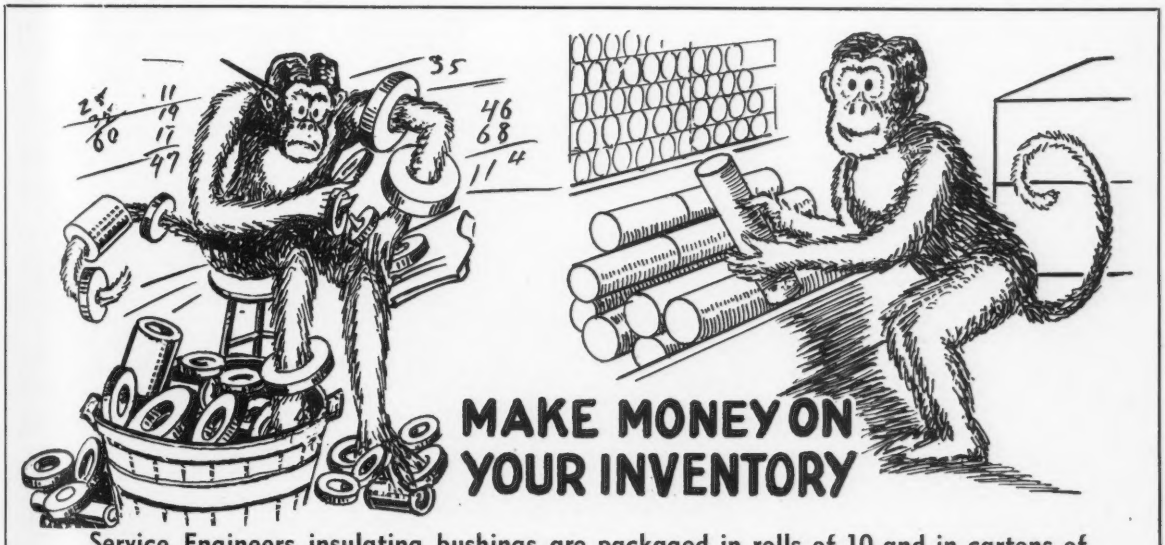
OHIO

CHENOWETH, WILLIAM F., 803 Uhrig Ave., Apt. #4, Dayton 6, Ohio (111 N. Williams St.)
ELDER, LOWELL L., Columbia Gas System Service Corp., 99 N. Front, Columbus, Ohio (Engineering Corp.)
LANG, ALBERT A., 13308 Claiborne Rd., E. Cleveland 12, Ohio (Pioneer Alloy Products Co., 16601 Euclid Ave.)
NORD, G. L., Schauer Mfg. Co., Box 95, Deer Parke Station, Cincinnati 36, Ohio (2060 Reading Rd.)
HOCKER, C. RICHARD, The Duriron Co., Mountain Rd., Dayton, Ohio (Basking Ridge, Rd. 1, New Jersey).
WEST, LEWIS H., 885 E. Archwood, Akron, Ohio (500 Welcome Ave., Norwood, Penn.)

PENNSYLVANIA

BOSSERT, EARL D., 1990 Clearview Ave., Norristown, Penn. (Bell Telephone Co., of Pa., 1401 Arch St., Philadelphia, Penn).
DECOWSKY, GEORGE N., Philadelphia Electric Co., 900 Sansom St., Philadelphia 5, Penn. (Ayer Bldg., 210 W. Washington Sq.)
DONNELLY, JOSEPH B., Dept. of Public Property, 1320 City Hall Annex, Philadelphia 7, Penn. (Dept. of City Transit).
FISHER, LEROY E., 2611 Wood Rd., Holmes, Pennsylvania (Petrolite Corp., Tretolite Div., 237 Pacific Webster Groves 19, Missouri).
McPHERSON, JOHN L., No. 3 Murdock Ave., RFD #2 Library, Pennsylvania (301 Griffin Ave., Pittsburgh 10, Pennsylvania).
MULLIN, GROVER E., Dowell, Inc., P. O. Box 151, Ardmore, Penn. (Rm. 1305, Morris Bldg., 1421 Chestnut, Philadelphia 2, Penn.)
MUSCHENHEIM, JR., HARRY, Sun Pipe Line Co., 1608 Walnut St., Philadelphia 3, Penn. (Susquehanna Pipe Line Co.)
WHITE ROBERT L., R.D. #1, Wexford, Pennsylvania (P. O. Box 63, Degolia, Penn.)
VAN DE WATER, DONALD F., Sun Pipe Line Co., 1608 Walnut St., Philadelphia 3, Penn. (Susquehanna Pipe Line Co.)

(Continued on Page 16)



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Changes of Address—

(Continued from Page 15)

SOUTH CAROLINA

FETNER, JR., CHARLES J., E. I. DuPont de Nemours & Co., Camden, South Carolina (U.S. Steel Co., Research Lab., Vandergrift, Pennsylvania).

TEXAS

BLACKBURN, PHILIP C., Drawer D, University Station, Austin 12, Texas (1018 No. Jefferson, Mt. Pleasant, Tex.)

DAVIS, JACK G., Transcontinental Gas Pipe Line Corp., P. O. Box 296, Houston, Tex. (1614 Milford).

DONNELLY, PATRICK R., Box 686, Smithville, Texas (902 F. Bougainville, Oceanside, California).

FINCHER, D. R., Tide Water Assoc., Oil Co., P. O. Box 246, Weimar, Texas (P. O. Drawer 561, Palestine, Tex.)

GOELZENLEUCHTER, ALVIN H., 126 W. 6th, Freeport, Texas (3211 Elser, Houston, Tex.)

GRIFFITH, DEAN O., Shell Pipe Line Corp., Box 318, Houston, Tex. (2414 Delafield St.)

HENRY, ERNEST L., 549 S. College, Bellaire, Texas (Box 173, Cleveland, Tex.)

HOWELL, KENNETH S., P. O. Box 1069, Wharton, Texas (829 Columbia, Houston, Tex.)

IRVING, RALPH, R.D. #1, Box 914, La Porte, Texas (Vapor Honing Co., 515 Sterling Bldg., Houston, Tex.)

KLEESPIES, JR., HENRY S., 3923 5th St., Port Arthur, Tex. (5237 32nd St.)

KNOX, JOHN A., 106 E. Parker, Midland, Texas (The Western Co., Box 310).

LEBLANC, ROLAND L., Cities Service Refining Co., 1213 Bernard, Pasadena, Texas (20 Eveland St., Maplewood, La.)

McGARY, S. U., Midwest Pipeline Service Co., 3854 Arbor, Houston 4, Texas (1513 Woodcrest).

McKENNEY, WARREN E., James E. Mavor Co., Room 527 M & M Bldg. Houston, Tex. (Room 514).

MILLER HARRY J., Amercoat Corporation, 1227 Levee St., Dallas 2, Texas (4223 Emerson Ave., Dallas 5, Tex.)

NEWELL, THOMAS M., 1420 E. 35th St., Odessa, Texas (212 Santa Rita).

NICHOLS, WILLIAM B., Texas N.M. Pipe Line Co., Box 1510 Midland, Texas (The Texas Pipe Line Co. Box 2332, Houston 1, Tex.)

OSBORN, OLIVER, Box 887, Lake Jackson, Texas (225 Jasmine).

PARR, JAMES M., Parkerizing, Inc. of Texas, Box 9286 Houston, Texas (6506 Navigation Blvd.)

PARR, MACGREGOR A., Parkerizing Inc. of Texas, Box 9286 Houston 11, Tex. (6506 Navigation).

RHODES, H. A., Transcontinental Gas & Pipeline Corp., 3100 Travis, Houston, Texas (2100 Neils Esperson Bldg.)

ROBBINS, KENNETH W., Otis Pressure Control, Inc., Box 7206, Dallas, Tex. (2402 Broad St., Houston, Tex.)

SIMS, JOHN J., Continental Products Corp., Box 606, Canyon, Tex. (D. W. Haering & Co., Inc., Box 105 Station 1).

SLAVIK, EDWARD W., Slavik Bros., 1108 Wilson Bldg., Corpus Christi, Texas (Dowell Inc.)

WALKER, ROBERT B., Magnaflux Corp., 3127 N. Muskingum, Odessa, Texas (2110 N. Muskingum).

WATSON, ROGER D., 7759 Rosedale Drive, El Paso, Tex. (346 McCune).

ZARUBA, RICHARD S., 5624 Community Drive, Houston 5, Tex. (1748 Richmond).

WYOMING

DEACON III, WILLIAM T., Big Horn Wyoming (Solvents & Plastics Co., 8032 Forsyth Blvd., St. Louis, Mo.)

FOREIGN

DUTTON, W. L., F. E. Shaw Limited, 530 So. Vidal St., Sarnia, Ontario, Canada (Union Gas Co. of Canada, Ltd., 5th St. Chatham, Ontario, Canada).

HORNE, ALBERT N., Trans-Northern Pipe Line Co., Hermant Bldg., 21 Dundas Square. Toronto 1, Ontario, Canada (RM. 1011, 25 Adlelaide St., East).

PLOG, CHARLES B., Standard-Vacuum Oil Co., Wilson Rd., Bombay, India (Marketing Engr. Dept. 86 Trinity Pl. New York, N. Y.)

NEW CORPORATE MEMBERS

O. R. BURDEN CONSTRUCTION CORPORATION
Tulsa, Oklahoma
O. R. Burden, Rep.

CENTRE BELGE D'ETUDE DE LA CORROSION
Brussels, Belgium
Marcel Pourbaix, Rep.

CATHODIC PROTECTION SERVICE
Houston, Texas
E. P. Doremus, Rep.

HOLCOMBE & STEARNS, INC.
Shreveport, Louisiana
Tom L. Holcombe, Rep.

MIDDLE WEST COATING & SUPPLY
Tulsa, Oklahoma
Maynard H. Jackson, Rep.

MID-VALLEY PIPELINE COMPANY
Longview, Texas
G. K. Doss, Rep.

SOUTHERN PRODUCTION COMPANY, INC.
Shreveport, Louisiana
Dick T. Fenwick, Rep.

UNION GAS COMPANY OF CANADA, LTD., Chatham, Ontario
G. I. Russell, Rep.

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Roskote's drying speed and handling ease cuts man-hours from work schedules and speeds pipe-line progress. That saves real money! Yet Roskote costs only 3¢ per square foot of coverage.

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•

Write for bulletin containing complete technical specifications, chemical and electrical properties and application information. Ask for the Roskote special trial order offer.

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MANUFACTURERS OF QUALITY INDUSTRIAL COATINGS RESISTANT TO CORROSION BY ACIDS, ALKALIES, ELECTROLYSIS, HEAT, MOISTURE AND WEATHER.

NEW PRODUCTS —Materials—Service—Literature

Magic Chemical Co., Brockton, Mass. are manufacturers of a self-cold-curing rubber compound to be applied as a protective coating. The compound is said to provide excellent protection against corrosion, abrasion and chemical wear. The plastic rubber is in paste form and can be applied with a spatula.

•

Graver Tank and Manufacturing Co., Inc., East Chicago, Ind. has published a booklet on the various types of tanks made by the company. Principal features of double decked floating roof, center weighted floating roof, expansion roof, and the "Graver Vapor-Mizer" tanks are illustrated.

•

Lead clad steel and lead clad copper are the subjects dealt with in a 22-page booklet published by Knapp Mills, Inc., 23-15 Borden Ave., Long Island City, New York. Title of the book is "The History and Development of Ferrolum Lead Clad Steel and Cupralum Lead Clad Copper." The book claims lead cladding provides a solution to corrosion problems developing in the manufacture, transportation, storage and processing of sulfuric acid and in the handling of radioactive materials.

•

New Information on atmospheric exposures of steels containing nickel and copper is provided by The International Nickel Co., Inc., 57 Wall St., New York 5, N. Y. in a reprint from the American Society for Testing Materials Proceedings, Vol. 48, 1948, titled "Atmospheric Durability of Steels Containing Nickel and Copper—Additional Exposure Data," by N. P. Pilling and W. A. Wesley. The new data are supplementary to those in the article "Atmospheric Durability of Steels Containing Nickel and Copper" by the same authors reprinted from ASTM Proceedings in 1940. The 8-page supplement contains 8 tables and charts. Observations, based on some specimens after 22 years' exposure, provide comparisons of results for moderate and heavy industrial, marine and rural atmospheres. Beneficial effects of varying percentages of nickel and copper and other alloying elements are shown. Tests show it is more significant to compare steels on the basis of how long a time is required to arrive at a given unit weight loss than to compare them on the basis of weight loss over a fixed period of time.

•

Midwestern Engine and Equipment Co., Tulsa, Okla., recently announced the purchase of land and plans for construction of a new building near Tulsa. Midwestern officials said the new plant was necessary because of increased business. The company recently introduced "Protecto Wrap." The wrap is applied to the pipe by "flashing" with a low temperature torch thereby melting the enamel contained within the material itself.

•

Bryton Inc., Elizabeth, N. J., has developed a high molecular weight sulfonate to help meet the demand for better rust protective compounds. The product, Bryton No. 490, is a fully refined, 490 molecular weight, oil soluble sodium sulfonate.

•

Hampel Modjeska Laboratories has been formed to conduct research and development studies, technological and economic evaluations and consulting work in industrial chemicals, electrochemical and electrometallurgical processes and products, and the recovery and utilization of strategic metals. Clifford A. Hampel, one of the partners, was formerly supervisor of extraction metallurgy at Armour Research Foundation. R. Scott Modjeska, the other partner, is the founder and director of Scientific Control Laboratories of Chicago, Ill. The new firm will use the facilities of Scientific Control Laboratories, in Chicago.

•

Monsanto Chemical Company's Western Division has announced completion of a new plant at Santa Clara, Calif., to manufacture butylated melamine and urea resins. The resins, to be marketed under

(Continued on Page 18)

AT LAST! AN ECONOMICAL, SHOCK RESISTANT INSULATING COUPLING

Until recently mechanical weakness and high costs have discouraged the large-scale use of insulating couplings on gas distribution systems. Now comes PESCO . . . safe, economical, rugged, easy to install, and assuring permanent electrical insulation.

Insulate your distribution system with

PESCO INSULATING COUPLINGS*

PESCO couplings are designed and built to stand up under all types of extreme operational conditions. They are molded of nylon under high pressure. Nylon is a thermoplastic resin which is comparable to thermosetting resins in physical properties and far superior in chemical resistance and the ability to withstand bending, side thrust and shock. They stand pressures up to 1100 psi and are not affected by temperatures up to 300°F. Molding forms perfect threads and a "di-electric wall" inside the coupling to provide fool-proof electrical insulation and added sealing ability. A special locking device prevents the coupling from turning or slipping in its steel sleeve.

PESCO couplings may be installed by your regular workmen with their standard operating procedures. Available in all sizes from ¾" to 2".

* Patent Pending

PLASTIC ENGINEERING AND SALES CORP.

P. O. BOX 1037 **FORT WORTH, TEXAS**

New Products—

(Continued from Page 17)

the trade name "Resimene" are used by the paint industry in the manufacture of fast-drying, durable surface coatings for appliances and furniture.

•

Chemical Coatings and Engineering Co., Chester, Pa., is engaged in the sales and engineering of corrosion control compounds based on Neoprene. The coatings range from heavy duty tank lining compounds to maintenance coatings. The company also designs special resin coatings to meet specific requirements.

•

Dow Chemical Co. has taken over the sale of magnesium anodes from Dowell, Inc. The company announces the change was made to meet the need for closer coordination between research and development, production and sales.

•

American Wheelabrator & Equipment Corp., Mishawaka, Ind., manufactures a liquid rust inhibitor which it states embodies two characteristics new to inhibitors: Being in liquid form it goes into solution immediately; it virtually eliminates the staining normally expected with inhibited water. Name of the product is "Anarust." The company also markets abrasives for wet blasting machines in sizes from 80 to 2500 mesh. Another product, "Anaset," is an anti-packing chemical.

•

Knapp Mills Inc. is marketing a new heavy duty grease lubricant, "Lead-Lube." The company states the significant feature of the new lubricant is its extremely high metallic lead content in the form of a pulverized lead dust, kept in permanent suspension by the Knapp process. Advances in powder metallurgy which made metallic lead available in dust form and the development of the proper grease composition to hold the lead in suspension made the product possible, the firm reports.

American Cyanamid Co., New York, N. Y. is producing "Melmac" Resin 248-8, a melamine resin providing finishes for automobiles, kitchen cabinets, alkali-resistant finishes for washing machines and other uses.

•

"Dressertape," a new polyvinyl chloride pipe tape has been announced by Dresser Manufacturing Division, Dresser Industries, Inc., Bradford, Pa. The new tape with 10,000-volt dielectric strength is said to provide effective protection against water, salt water, acids, alkalies, oil and soil chemicals.

The tape is applied cold and requires no "setting-up" period and is available in 10 mil two inch wide size but will be available in a variety of sizes to meet complete pipe joint and pipe protection requirements.

•

Hamilton Standard Division of United Aircraft Corp., and the Bart Laboratories Co., Inc., Belleville, N. J. have announced the development of a process for nickel coating aluminum. The announcement states the process combines the hardness and corrosion resistance of nickel with the advantages of aluminum. A synthetic rubber compound provides a bond of extremely high adhesion or tensile strength, between the two metals according to the announcement.

•

The Bristol Co., Waterbury, Conn., has published two bulletins. One bulletin describes the Dynamaster Electronic Potentiometer and Bridge Instruments for measuring variables in temperature, pH, speed, voltage, power, current, smoke density, thickness, strain and other uses. The other describes the firm's Open Channel Flow Meters used in the measurement of flow of water, sewage, industrial plant effluent and other liquids through weirs and flumes of all types.

•

Mid-America Steel Warehouse, Inc., Chicago, Ill. recently announced the development of a harder, more durable coating for protecting steel sheets against corrosion and excessive heat. The new product, "Leafcote," is bonded and baked on steel sheets that have been degreased, pickled and phosphatized. The company claims the product draws and forms without peeling or cracking. The new coating can be used both for prime or finish coatings.

•

National Carbon Co., a division of Union Carbide and Carbon Corp., has announced release of a new Catalog Section, on "National" Graphite Combustion Chambers with "Karbate" brand impervious graphite burner nozzles. The chambers are designed for burning corrosive, wet gases at very high temperatures.

•

Tube-Kote, Inc., 2520 Holmes Road, Houston, Texas has completed a new $50,000 office building on the grounds of the company's 15-acre plant. The company applies thermosetting plastic coatings to oil field and chemical industry pipe and tubing.

•

Armco Type 317 stainless steel filter screen in use over 12,000 hours at a Baltimore, Maryland sewage disposal plant shows no sign of corrosion damage, according to a report from the company's Middletown, Ohio offices.

•

Hayden and Co., 53 West Jackson Blvd,. Chicago has been appointed to represent Colonial Iron Works Co., Cleveland in Northern Indiana, Northern Illinois, Western Michigan, Eastern Iowa and Wisconsin.

•

Glasfab, an open-weave glass fibre material is produced in widths of two to 45 inches and in rolls of 50 to 500 yards. A 36-inch, 300-foot roll weighs 9.5 lbs. It is made by Twinsburg-Miller Corp., Twinsburg, Ohio.

•

Associated Research, Inc., 3750 West Belmont Ave., Chicago 18, Ill. has issued Bulletin 10-A, available on request, which describes its full line of electrical testing instruments, many used in underground corrosion testing.

•

Glass Fibers, Inc. Toledo, Ohio is producing a sub-micron sized glass fiber which is a chemical duplicate of quartz. The fiber, now going wholly to the armed services except for small experimental quantities, is being made into paper used as a heat, chemical and electrical resistant material.

•

Control Valves designed to handle liquid nitrogen at —350 degrees F, pressures up to 3000 psi, red fuming nitric acid at room temperatures and superheated steam up to 1000 degrees F are manufactured by Annin Co., 3500 Union Pacific Ave., Los Angeles 23, Calif. The single seat valves are self balanced. Teflon seat seals and radiation fins for extreme temperatures are available. A feature of the valves is the fact they can be serviced without removal from the line. The lower half of the valve body is easily replaced with minimum down-

(Continued on Page 19)

★ Not an oil—a chemical that dissolves and prevents rust.

★ Expands and contracts with metal—stops peeling and blistering of paint coat.

★ Provides perfect surface for painting.

★ One gallon covers approximately 1200 sq. ft.

Rust deposit on steel forms a pitted surface.

Old method of applying oil base paint after sanding or brushing leaves rust in pits which later break through.

Lowell Metal Primer goes into the pits, dissolves ALL the rust and seals the surface — stops future paint failures.

Apply Lowell Metal Primer with cloth, brush, spray or by dipping. Watch it dissolve rust and seal the surface against future rust. It expands and contracts with the metal which prevents peeling or cracking like oil base primers. Use on damp or dry surfaces — dries in one hour . . . covers two to four times the surface of oil base paints; priced approximately the same.

USE Lowell FOR PRIMER BEFORE PAINTING

Metal roofs, iron fences, gutters, metal window sash, farm equipment, metal tanks and stacks, poles, any surface subject to rust or oxidation.

GENSCO CHEMICAL DIVISION
1834 NORTH KOSTNER AVENUE • CHICAGO 39, ILLINOIS

New Products—

(Continued from Page 18)

time. General Catalog 1500 B, describing all Annin control valves is available on request.

•

Corrosion-Induced changes in the crystal structure of stainless steel and high alloy steel aircraft exhaust systems are used in a testing method called Magne-Probe. The device consists of a probe about the size of a watch, and an indicating meter 2 x 3 x 4½ inches connected by a flexible cable. After the device is plugged into a suitable ac power source, the device is adjusted to predetermined sensitivity depending on the kind of test to be made. When the three prongs of the probe are slid along the metal surface the meter records the degree of magnetism. When the magnetism indicated exceeds predetermined levels the point at which the reading is made is marked for repair. Parts in place may be tested. The device may be used also to test welds defective because of excessive temperatures. American Instrument Co., Inc., Silver Spring, Md., is manufacturer.

•

Wall Colmonoy Corp., 19345 John R. Street, Detroit 3, Mich., has developed a light weight Spraywelder pistol which, using Colmonoy powders, oxy-acetylene flame and air as a powder propellant, deposits on base metal a layer of fine particles of the alloy partially bound together. After the required thickness is deposited the alloy layer is fused to the base metal to form a dense, hard, wear and corrosion resistant coating. Three Colmonoy alloys are currently available for spray welding. The Spraywelder also can be used to apply coatings of powdered metals other than hard alloys.

•

Acme-Fisher Division, Broadway Rubber Corp., P. O. Box 15066, Houston 20, Texas, has issued a 16-page brochure describing the kinds of materials and types of applications of the "Laybond Family of Protective Membranes."

•

Zephyrweld Stainless Steel Light Weight Welding Fittings, manufactured by Tri-Clover Machine Co., Kenosha, Wis., consistent with schedules 5s and 10s for light gauge pipe are described in a 16-page brochure available on request. Physical characteristics and size schedules for all classes of fittings are included.

•

Michigan Pipe Co., Bay City, Mich., describes its lines of wood stave pipe, wood-lined pipe, Saran rubber lined pipe, stainless steel fabricated tubing and fabricated Monel tubing in a loose leaf catalog available on request. The wood-lined pipe, for example, which has been used in the paper industry for many years to handle corrosive slurries, is recommended for handling dilute mineral acids and process water at all pHs as well as dilute caustic soda, slurries, pulps and abrasives. Linings may be Douglas fir, redwood and others to order. Piping of interval diameters from 4 to 40 inches is available. Joints can be connected with standard pipe fittings, and the pipe may be cut and flanged in the field, field welded.

Lucite equipment for plating operations, laboratory and pilot plant work are available from Singleton Co., 10516 Western Ave., Cleveland 11, Ohio.

•

Owens-Corning Fiberglas Corp., has established branch sales offices at Tampa, Florida and New Orleans, La.

•

Iolyte Polyester Laminated Sheets, in continuous strips of any desired length, from 8 mils to ¼-inch or more thick are available from Industrial Organics Corp., 59-31 Fifty-Fourth Street, Maspeth 78; New York. With tensile strength equivalent to steel by weight, the material weighs one-fifth as much as steel by volume, being lighter than aluminum or magnesium. With low water absorption and good electrical properties, the material is virtually shatterproof and scratchproof, manufacturers say. It may be fabricated into pipe, tanks or molding shapes. The filler may be glass fiber, cotton cloth, Orlon, Nylon or other synthetic or natural fibers.

•

Glass Fibers, Inc., has opened a branch sales office at Chrysler Building East, New York 17, New York.

•

Gulf States Asphalt Co., P. O. Box 508, South Houston, Texas is marketing two pipe coating products. Gulf-Seal Pipe Primer No. 474 is for cold priming prior to application of hot Gulf-Seal pipe coatings or as storage protection against

(Continued on Page 20)

...MEN AT WORK!

Beneath the surface of this undisturbed street in Washington, D. C. men are at work . . . reconditioning water pipelines with the Centriline process. Above ground, traffic flows smoothly . . . unobstructed by the usual men, machinery and excavations. Because the Centriline process centrifugally applies cement-mortar lining to pipes in place, excavation time, overall costs and interruption to street traffic are kept at an absolute minimum. Couple these advantages with the fact that Centrilining permanently prevents corrosion and tuberculation, increases carrying capacity, reduces pumping costs, gives new pipe service at a fraction of the cost of new pipes, and you have the reason why more and more city engineers and officials are specifying Centriline for their pipeline projects.

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New Products—

(Continued from Page 19)

corrosion. It can be applied by spray, brush or dip methods. A natural asphaltic material dissolved in solvent, it dries rapidly, leaving an elastic adhesive coating, manufacturers say. Resistance for five days to 5 percent concentrations of sodium hydroxide or potassium hydroxide, 1 percent solutions of sulfuric acid or water saturated with hydrogen sulfide is reported. It can be applied to moist surfaces. Gulf-Seal Pipe Coating No. 434, an asphalt bituminous compound containing a finely divided amorphous type filler, forms a tough elastic coating with good abrasion resistance. It is resistant to shock at low and will not flow at high temperatures, the manufacturers state. Midwest Pipeline Service, 3854 Arbor Street, Houston also is a distributor.

•

Tuffite, a phenolic condensate compounded with macerated canvas, available in moulded or sheet form is manufactured by Stewart R. Browne Mfg. Co., Inc., 258 Broadway, New York 7, N. Y. With a tensile strength of 6200-7000 pounds per square inch and good resistance to impact, besides other desirable physical characteristics, it has a dielectric strength of 175 volts per mil at 60 cycles (inst) and 250 volts per mill at 60 cycles (step). It is useful for both bushings and gaskets for insulating standard fittings and is provided also in couplings for electrical insulation of line segments.

•

Electro-Stops, designed to insulate sucker rod strings, tubing and flow lines from destructive galvanic and stray currents are manufactured by M & N Machine Co., 1609 E. Slauson Ave., Los Angeles 11, Calif.

•

Radiation Measurements on large liquid or solid samples can be made with minimum geometry errors with the Ohmart Model AH-2 Gammometer manufactured by the Ohmart Co., 2347 Ferguson Road, Cincinnati 38, Ohio. The Ohmart instruments use radioactive energy converted directly into electrical energy to power the instrument, eliminating the need for high voltage supply. The instrument is calibrated in terms of radium (standard), cobalt 60 or iodine 131. Precision is better than plus or minus 1 percent of full scale.

•

Organic Methods of Scale and Corrosion Control, a 40-page booklet available from D. W. Haering & Co., Inc., P. O. Box 6037, San Antonio, Texas outlines general methods of water treatment covering vegetable and organic chemicals, organic chemistry, carbohydrates, colloidal chemistry, high pressure equilibria, organic water treatments and gives detailed descriptions of the composition, function and use of glucosides. A section on water problems covers domestic, boiler, cooling, steam and return condensate waters, brines, pasteurizer and bottle washer waters. Charts and diagrams illustrate factors in controlling scale and corrosion by waters used for various purposes. A section on analyses tells how effectiveness of treatment may be evaluated. Curves illustrate various studies of condensate corrosion, boiler scale and others. Sampling and proportioning procedures are defined. The company's glucosate products are described and their function explained.

•

Rustshield 2, a phosphatizing treatment said to produce an oil-retaining rust resisting surface on moving metal parts is described in a booklet available from Octagon Process, Inc., 15 Bank St., Staten Island 1, N. Y. It is applied by dipping in a 5-stage process.

•

Permutit Company, 330 West 42nd St., New York 36, N. Y. has issued an enlarged edition of its Water Conditioning Data Book superseding the 1949 edition. The book includes 77 tables, useful to the engineer concerned with water conditioning. The data tabulated cover a wide range of information, such as: Water equivalents, gallons into other units, tank capacities by diameter, horizontal cylinder tank capacities by diameters, contents of standard dished heads, pressure equivalents, pump power requirements, cost per kilowatt hours and per million gallons, friction of water in pipes, frictional resistance to flow of water, backwash flows, standard weight welded and seamless pipe, resistance of valves and fittings to flow of fluids, orifice tables, rectangular weir tables, impurities in water; formulae, molecular and equivalent weights and conversion factors to $CACO_3$; many tables relating to chemicals used in water treatment, hydrogen cation exchanger H reactions, anion exchanger reactions, reduction of calcium and magnesium alkalinities by the cold lime process, phosphate treatment of boiler feedwaters, saturated steam table, fundamental data relating to sieves of the standard screen scale, and many others. The book, 4¼ by 7 inches, with fabrikoid cover, contains 102 pages of tables. It is available free to practicing engineers and those working with water conditioning problems.

PERSONALS

Ian Steven has been named controller for Hills-McCanna Company, Chicago.

•

Arthur E. Gray has been appointed assistant manager for tar base coatings by Pittsburgh Coke and Chemical Company. He will be in the Pittsburgh office of the firm.

•

William H. Worrilow, Jr., has been made general sales manager and **Robert C. McConnell** has taken the newly created position of director of industrial relations of Lebanon Steel Foundry, Lebanon, Pa.

•

H. E. Burtner has joined the sales force of Midwestern Engine and Equipment Co., Tulsa, to handle the company's pipeline wrapping and supply materials.

•

V. J. Scarola, in charge of the Tapecoat Company's New York office for the past seven years has been named manager of sales for the firm with headquarters in Evanston. **John G. Bolling** is manager of utility sales, **John Walsh,** industrial sales; **Burt Schmidt,** Midwest sales and service and **Louis** Zito, Eastern sales.

•

Wendell P. McKown, Jr., has been named works manager for The Cooper Alloy Foundry Co., Hillside, New Jersey.

•

Louis Fernandez, group leader in the research department of Monsanto Chemical Company's phosphate division at Anniston, Ala., has been transferred to the division's technical sales department at St. Louis. He will specialize in problems related to formulation and application of synthetic detergents.

•

Clayton V. Ing, Jr., has joined the staff of Plastic Engineering and Sales Corp., Fort Worth. He formerly was with Southwestern Gas and Electric Company. He holds a degree in electrical engineering.

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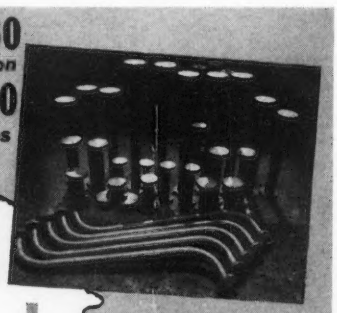

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Corrosion Abstracts

CORROSION CONTROL — NATIONAL ASSOCIATION OF CORROSION ENGINEERS

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Vol. 8 May, 1952 No. 5

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NATIONAL ASSOCIATION of CORROSION ENGINEERS

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1. GENERAL

1.5 Directories of Material

1.5

Review of Materials Engineering Developments in 1950. T. C. Du Mond. *Materials & Methods,* **33,** 85-96 (1951) Jan.

Covers irons and steels, nonferrous metals, nonmetallic materials, fabricated parts and forms, finishes, heat treating, cleaning and finishing, welding and joining testing and inspection.—BLR.

1.7 Organized Studies

1.7.1, 3.6.9, 5.2.1

2nd Report of the Gas Works Safety Rules Committee: Electrolytic Corrosion and the General Theory of Corrosion. Institution of Gas Engineers. Inst. Gas Engrs. Communication No. 374, July, 1950, 43 pp.

Describes types of electrolytic corrosion, its mitigation, testing methods, interpretation of results, etc. Most of the information relates to gas mains, reference being made to stray current corrosion, contact corrosion and cathodic protection. 64 references.—BNF.

1.7.1, 5.4.5

Anti-Corrosive Work in Belgium. ABEM Committee IV. *Chim. Peintures,* **13,** No. 6, 278-282 (1950).

Centralized anti-corrosive paint work in Belgium during 1949 is reviewed. Investigations in progress include development of accelerated weathering cycles, exposure testing at 4 stations and special researches on the effect of steel composition, method of surface preparation, metallization treatments and primer composition. Most investigations are in an early stage, but interim examination

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CODE OF AGENCIES SUPPLYING CORROSION ABSTRACTS

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BLR—Battelle Library Review, Battelle Memorial Institute Library. 505 King Ave., Columbus, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum, 26 Portland Place, London W#1, England.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana. Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

after 9 months showed: 1) that red lead or zinc oxide/linseed oil and aluminum/bitumen primers were outstanding. 2) aluminum paints over primers were poor. 3) Chlorinated rubber paint systems did not behave well.—RPI.

1.7.2

Industry Girds for Stronger Corrosion Fight. BILL CZYGAN. *Iron Age,* **166,** 85 (1950) Nov. 23.

Describes new laboratories and exposure racks recently opened by International Nickel Co. at Kure Beach, N. C. Facilities are available to industry on a cooperative basis.—BLR.

2. TESTING

2.2 On Location Tests

2.2.1, 1.7.1

Ohio River Division Corrosion Problems. J. A. DAVENPORT. Ohio River Div., Corps. of Eng. Paper before NACE, 6th Annual Conf., St. Louis, April 4-7, 1950. *Corrosion,* **7,** No. 2, 42-46 (1951) Feb.

The organization and duties of the Ohio River Division, Corps of Engineers, U. S. Army is discussed. The locations of tests conducted in recent years is given as well as corrosion studies underway and in contemplation. Cooperative studies and tests on stainless steels, low alloy steels, carbon steels and aluminum have been conducted. Steels 302 and 304 have given good performance and while steels 405, 410 and 430 do not perform as well they may be satisfactory in resistance to corrosion. Of the commercial low alloy steels tested, Cor-Ten alone showed any superiority. In the alloy steels group, the only outstanding material is a recently patented chromium-titanium steel which out performed all others in every test. Results of different types of painting tests including varnishes and vinyls are outlined. Surface preparation necessary before application of the coatings and corrosion caused by atmospheric exposure is reported. A summary of cost figures is given.—INCO.

2.2.5, 4.6.1, 5.4.5

Evaluation of Underwater Paints for Steel Surfaces. W. HUSSE. *Paint and Varnish Production Mgr.,* **30,** 7, 13-15 (1950) Apr.

Presents results of a study initiated by the German Government in 1936. Because of World War II and the postwar adjustment period, results were not made available until Dec. 1949, when they were given in the form of a report in Berlin.—BLR.

2.3 Laboratory Methods

2.3.2, 5.4.5

Electrochemical Evaluation of the Anticorrosive Power of Chromate Pigments Immersed in a Liquid. L. CAVALLARO, C. BIGHI AND G. MANTOVANI. *Pitture e vernici,* **6,** No. 6, 229-233 (1950).

The amperometric method was used for comparing the anti-corrosive power of various chromate pigments (with or without the addition of red lead) in an alkyd medium with that of red lead in linseed oil. The paints were applied to mild steel panels and immersed in water, 3 percent sodium chloride solution, and hydrochloric acid and sodium hydroxide of various concentrations. In water, aqueous sodium chloride and dilute (up to 0.01-N) hydrochloric acid and sodium hydroxide, red lead oxide and a zinc chrome/red lead oxide mixture gave the best results, followed by a lead chromate/red lead oxide mixture, and then by straight lead chromate, straight zinc chrome and particularly orange lead chrome were far less effective. In 0.1-normal hydrochloric acid the order was the same, but no paint was entirely satisfactory. In 0.1-normal sodium hydroxide all paints failed badly, the red lead oxide and lead chromate paints being particularly unsatisfactory. The protective action of lead chromate paint immersed in 0.001-normal hydrochloric acid is less if the liquid is in motion than if it is stationary, supporting the view that the anti-corrosive action is due to corrosion inhibition by chromate ions in solution. More than 20 references.—RPI.

2.3.2, 4.6.11, 3.2.2

On the Cracking of Aluminum-Magnesium Alloys in Contact with Mercury. A. JACQUET AND A. R. WEILL. *Rev. aluminium,* **27,** No. 172, 442-451 (1950) Dec.

It is sought to determine up to what point the mercury salt test could give useful information in the case of aluminum alloys with a high magnesium content, showing internal stresses and submitted to the action of a saline atmosphere. Their study was focussed on the case of compressed air cylinders made of aluminum alloys with 7 magnesium, used aboard ships and exposed to seawater corrosion. A few abnormal fractures occurring under service conditions, when several thousands of this type of 7 magnesium cylinders were used, led to an inquiry to determine the causes. The question arose as to whether the mercury salt test would permit the finding of a relation between the tendency of this alloy of exceptionally high magnesium content to crack in a saline atmosphere and the structural heterogeneities —INCO.

2.3.2

High-Speed Rotor Tests of Paints for Under-Water Services. F. WORMWELL, T. J. NURSE AND H. C. K. ISON. *J. Iron Steel Inst.,* **165,** Pt. 3, 297-299 (1950).

A discussion of a paper previously noted (*Review,* 1949, 83).—RPI.

2.3.4, 8.8.3

Traces of Chromium in Zinc Plating Baths. E. I. SERFASS AND M. H. PERRY. *Plating,* **37,** No. 10, 1057-1059 (1950) Oct.

Full details are given of a method for determining chromate ion in acid or alkaline zinc plating baths. After oxidizing any reducing agents with nitric acid, diphenylcarbazide is added and the acidity brought to 0.2 normal by adding 6 normal sulphuric acid. The transmittancy of the solution is measured using a green filter and the chromate content read off a calibration chart. Alternatively, direct visual comparison may be made with Nessler tubes.—ZDA.

2.3.5, 3.6.5

A Micro Solution-Potential Measuring Technique. L. W. SMITH AND V. J. PINGEL. *J. Electrochem. Soc.,* **98,** 48-50 (1951) Feb.

Solution-potential measurements are used to predict corrosion susceptibility of metals or alloys when exposed to various media. Describes technique developed for measuring the solution potential of a metal or alloy on a micro scale. It consists of electrically insulating the polished and etched surface of the metal specimen with a transparent plastic film, puncturing the film over any desired microconstituent with the aid of a specially adapted hardness tester, and then determining the solution potential at the point of puncture. Includes photomicrographs.—BLR.

2.3.5

Oxide Film Formation on the Surface of Metals in Aqueous Solutions and the Evaluation of Their Standard Potentials. II. The Mercury Electrode. S.E.S. EL WAKKAD AND T. M. SALEM. *J. Phys. & Colloid Chem.,* **54,** 1371-1383 (1950) Dec.

Investigation described deals with metallic mercury. From a study of behavior of the electrode in the presence and absence of air after applying a special technique for removal of the oxide film, conditions under which a persistent oxide film is absent from the surface of metallic mercury in aqueous solutions were determined. Only under these conditions can the true thermodynamic standard electrode potential, as well as other electro-chemical properties of metallic mercury, be determined.—BLR.

2.3.5, 5.4.5

Electrochemical Studies of Protective Coatings on Metals. F. WORMWELL AND D. M. BRASHER. *J. Iron Steel Inst.,* **162,** No. 129 (1949); **164,** No. 141 (1950); Discussion, *Ibid.,* **165,** 299-300 (1950).

I. Electrode Potential Measurements on Painted Steel. In previous experiments on the use of measurements of electric potential to determine the protection from corrosion afforded by coatings of paint, observations were not made over a sufficient period. The authors describe a technique whereby the changes with time of the electrode potential of painted steel immersed in artificial sea water could be measured over long periods. Found that when the measurements were continued for several weeks, the potential at first fell and then increased to a maximum before it gradually fell to more negative values. The period required to pass the maximum is an indication of the useful life of the paint under the conditions studied. The authors describe the use of the technique to investigate the effect on corrosion of the thickness of paint, the type of surface finish on the steel, the method of treatment of the metal before painting, and the type of paint. II. Resistance and Capacitance Measurements on Painted Steel Immersed in Sea Water. As the interpretation of electrode potentials is complex the authors have extended the technique described in Part I to include measurements of electrical resistance and capacitance. The apparatus used is described. It was found that curves in which changes in capacitance, log resistance, and conductance were plotted against time could be closely correlated with curves showing the area rusted. A sudden increase in capacitance and conductance gave a good indication of the onset of rusting. Measurements of capacitance could also be used to obtain information about the properties of the film of paint, such as thickness and amount of water absorbed, during the early stages of immersion.—PR.

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Office of Technical Employment
5000 Richmond Street
PHILADELPHIA 37, PA.

2.3.7, 2.4.2, 5.9.2

Swirl Method for the Evaluation of Metal Cleaners. ROBERT H. TIERS. *Metal Finishing*, **48**, No. 9, 56-60 (1950).

A gravimetric method for evaluating metal cleaners is described, though it is admitted that further investigation of the method is required. Various preparations of soil mixtures are applied to weighed steel panels, and after reweighing, these are attached to a shaft which is rotated by a small motor in the cleaner to be evaluated. After a given time the panels are removed and weighed again and the loss of soil computed. The soil is made up of mixing various components, and is intended to represent a typical soil such as might be picked up by the metal in practice. There is need for further development work on this aspect of the test. The coating of the plate with the soil is done under controlled conditions. The apparatus used for the swirl test, and its method of construction are fully described and illustrated. It is pointed out that the efficiency of the cleaner in removing the soil is dependent on the temperature, the concentration, the rate of rotation of the panels, and the time during which the panel is in the solution, and therefore for comparing different cleaners, it is necessary to standardize these conditions rigidly. It is claimed that very reproducible figures have been obtained by this method. —MA.

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Sales Engineer to sell protective coatings in Gulf Coast area for well-established paint manufacturer in Houston, Texas. In reply please give age, education and experience. CORROSION, Box 52-6.

2.3.7

Testing Cement Base Paints and Dampproofers. WILLIAM M. SPURGEON. *ASTM Bulletin*, **1951**, 53-56+, Jan.

Tests made on 23 commercial cement paints, 21 of which are used for dampproofing masonry walls, show that they vary widely in porosity. Water absorptions range from 2.4 to 65.1 percent by weight and 7-day compressive strengths range from 0 to 3300 psi. In general, for comparable curing conditions, high absorption values accompanied low compressive strength and vice versa. The theory of dampproofing is discussed briefly, and the need for further development of a simple, short screening test to supplement weathering data for ce-

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ment-base dampproofing is shown. The need for establishing specifications for these materials is also pointed out.—BLR.

2.3.7, 5.4.5

An Apparatus for Measuring the Permeability to Water Vapour of Bituminous Emulsion Films. A. EVANS AND C. Q. KEILLER. *J. Soc. Chem. Ind.*, **69**, Suppl. Issue I, S1-S3 (1950).

Includes diagram and typical data.—BLR.

2.3.9

An Electron Diffraction Study on the Corrosion of Metals. (In English.) SHIGETO YAMAGUCHI. *Japan Science Review*, ser. 1, **1**, 24-31 (1949) Mar.

Experimental results obtained on a variety of metals over a period of several years are summarized. 10 references.—BLR.

2.3.10

Evaluation of Protective Coatings. Part I. Properties of Packaged Paint. Part II. Properties of Consistency. GEORGE S. COOK. *Paint and Varnish Production Mgr.*, **30**, 14-15+ (1950) May; **30**, 14-15+ (1950) Aug.

Gives details of standard methods for the above, suitable for use by the commercial user.—BLR.

2.4 Instrumentation

2.4.3

Measuring the Thickness of Thin Coatings With Radiation Backscattering. ERIC CLARKE, J. R. CARLIN AND W. E. BARBOUR, JR. *Elec. Eng.*, **70**, 35-37 (1951) Jan.

Describes nondestructive process which can be used in production wherever measurement is to be made of coating which has a different atomic number from the backing material.—BLR.

2.4.3

An Improved Type of Thickness Tester. (In English.) KAN-ICHI KAMIYOSHI. *Service Reports of the Research Institutes, Tohoku University*, ser. A, **1**, 335-339 (1949) Oct.

Describes magnetic tester by which thickness of a metal wall, when access cannot be gained to both sides, can be measured. It is portable, simple in operation, and durable and can be applied to nearly all sorts of curved surfaces. Maximum thickness is about 10 mm. for chromium-molybdenum steel and larger for mild steel, and accuracy is about 10 percent for mild steel of 5 mm. thickness.—BLR.

3. CHARACTERISTIC CORROSION PHENOMENA

3.2 Forms

3.2.3, 3.5.9, 6.5

Physics of Metals. Oxidation of Steels and of Alloys. (In French.) X. WACHE. *Metaux & Corrosion*, **25**, 267-276 (1950) Nov.

Surface oxidation of the above was investigated at high temperatures, with emphasis on iron, copper and nickel-base alloys. In all of the alloys investigated, it was found that distribution of the component elements in the oxide layer does not correspond to their concentration in the original alloy. Data are charted, tabulated and discussed. 17 references.—BLR.

3.2.3, 3.8.4

Kinetics of Solid Phase Reactions in Oxide Films on Iron; The Reversible Transformation at or Near 570° C. EARL A. GULBRANSEN AND ROSWELL RUKA. *J. Metals*, **188**, 1500-1508 (1950) Dec.

The forward and reverse reactions, $Fe_3O_4 + Fe \rightleftarrows 4FeO$ were studied by electron-diffraction methods. In thin films, the forward reaction occurs at temperatures 170° C below the equilibrium value. The mechanism of the forward reaction is shown to be governed by the diffusion of iron. Studies on the reverse reaction as a function of time, temperature and oxide composition indicate that nucleation and growth processes are rate controlling. Diffraction patterns, tables and graphs. 27 references.—BLR.

3.2.3, 6.3.18, 4.3.5, 3.5.9

The Kinetics of the Reactions of Vanadium with Oxygen and Nitrogen. EARL A. GULBRANSEN AND KENNETH F. ANDREW. *J. Electrochem. Soc.*, **97**, No. 11, 396-404 (1950).

A study is described of the reaction of rolled vanadium sheet with oxygen over the temperature range 400°-600° C. Colored films were formed. The parabolic rate law was found to fit the data obtained except for an initial deviation. The energy of activation is shown to be 30,700 cal per mole. The entropies and free energies of activation were calculated from the transition-state theory. Negative entropies of activation were observed. Vanadium oxidizes faster than titanium, but slower than tantalum, niobium, and zirconium. The reaction with nitrogen was studied over the range 600°-900° C, and it was found that the parabolic rate law fitted the data. The rate of reaction with nitrogen is much less than with oxygen at a given temperature. The former is not sensitive to pressure. No colored films were observed and it was therefore concluded that the nitride film was present during the reaction, but dissolved upon removing the gas. The nitride was stable to 1000° C. Vanadium reacts with nitrogen faster than zirconium, titanium, niobium and tantalum. Thermodynamic calculations were made on the following reactions: 1) decomposition of the several oxides and the nitrides, 2) the equilibrium between the oxides and oxygen, 3) the equilibrium between vanadium and the oxides, and 4) the reduction of the oxides by Hydrogen, carbon monoxide, and ammonia. Heating vanadium in high vacua resulted in no loss in weight. The vacuum microbalance was used in this work.—MA.

3.2.2, 8.8.5

Pitting Chief Hazard to Steel Ship Hulls. *Science News Letter*, **58**, No. 23, 361 (1950).

Regular painting usually controls hull pitting unless electrochemical effects due to dissimilar metal contacts or stray electric currents are present.—RPI.

3.4.6, 3.4.7, 5.8.2, 4.3.6

Role of Dissolved Oxygen During the Inhibition of the Corrosion of Iron by Sodium Phosphate Solutions. M. J. PRYOR AND M. COHEN. *Nature*, **167**, No. 4239, 157 (1951) Jan. 27.

Determination of the effect of dissolved oxygen on the corrosion rate of iron totally immersed in solutions of sodium phosphate at different pH values. The specimens were cut from 0.005 carbon, 0.0075 silicon, 0.013 sulfur, 0.003 phosphorus, 0.007 manganese, 0.018 nickel, 0.02 chromium, 0.003 copper, 0.12 oxygen, 0.018 nitrogen, 0.00009 hydrogen sheet. The first experinemts exposed the specimens to a 5 molar solution saturated with air. The results show that passivity is obtained at pH values above 7.25. Experiments under anaerobic conditions involved the large change in gaseous solubility on freezing the solution. The results show that once dissolved oxygen is removed from the phosphate it does not inhibit the corrosion of iron. The corrosion product in the absence of oxygen is a colorless tabular crystalline deposit. The experimental method and a graph of the result is given.—INCO.

3.5 Physical and Mechanical Effects

3.5.3

Gas Evolution in Liquids and Cavitation. P. H. SCHWEITZER AND V. G. SZEBEHELY. *J. Applied Phys.*, 21, 1218-1224 (1950) Dec.

Nine heavy lubricating oils, 4 light lubricating oils, 3 aircraft-engine fuels, 1 Diesel fuel and distilled water were tested for air solubility and for rate of solution and evolution of air when equilibrium is disturbed. A wide variation exists in solubility constants and rates but rate of evolution was always found to be proportional to supersaturation and rate of solution to undersaturation under otherwise similar conditions. The investigation gave some insight into the phenomenon of cavitation.—BLR.

3.5.4, 1.3

A Review of Some Effects of Light on Electrochemical and Corrosion Processes on Metals. L. YOUNG. Atomic Energy Research Establishment Report No. A.E.R.E. M/T.N.2, June, 1950, 9 pp.

Reviews information and theories on the acceleration of the oxidation of aluminum in air by ultra violet light, the Becquerel effect (production of a potential difference between two electrodes in an electrolyte when one is illuminated), the reduction of overvoltage by ultra violet light and the effect of light on wet corrosion. 40 references.—BNF.

3.5.3

Wear and Damage of Metal Surfaces with Fluid Lubrications. No Lubrication, and Boundary Lubrication. F. P. BOWDEN AND D. TABOR. Mechanical Wear, pp. 109-129, 1950. Book edited by John T. Burwell, Jr., 375 pp., obtainable from Amer. Soc. Metals, 7301 Euclid Ave., Cleveland, Ohio.

First, Bowden and Tabor discuss the damage of metals under conditions of fluid lubrication and consider the case of flat and curved surfaces and also the breakdown of fluid lubrication. Then they deal with the wear and damage of unlubricated metals and consider four different ways by which the metallic junction between sliding surfaces may be sheared: 1) Junction weaker than sliding metals, 2) junction stronger than one of the metals, 3) junction stronger than both metals, 4) junctions are of the

same material as both surfaces. The deformation produced by sliding is also discussed. Lastly, localized damage and wear under conditions of boundary lubrication is discussed with reference to boundary lubrication, the influence of temperature and the formation of soap films.—MA.

3.5.8

Fractographic Registration of Fatigue. C. A. ZAPFFO AND C. O. WORDEN. Paper before ASM. 32nd Ann. Conv., Chicago, Oct. 23-27, 1950. Am. Soc. Metals, Preprint 32, 12 pp. (1950).

Fatigue fractures of 75S-T6 aluminum alloy, mild steel and alloy steel were studied fractographically. Two distinctive patterns common to all specimens were found which characterize a condition of damage from fatigue stressing, one apparently representing a preliminary stage, and the second a final stage. The structures giving rise to the 2 patterns are "platy" and "fine lamellar," respectively, and are found on the facets of subsequent impact fractures to extend for a distance into the parent metal corresponding to the stressed zone. Their relationships to cyclic count and to proximity to the zone of maximum stress are briefly examined. The patterns clearly display a subdivided or mosaic constitution of the grain, with a structural reorganization caused by fatigue. Besides providing a new viewpoint for such phenomena as the known increase of damping with onset of fatigue, these patterns promise to reveal the fundamental nature of fatigue itself and perhaps also to provide a metallographic technique by which

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the occurrence and even the stages of fatigue failures can be recognized. A tentative explanation for fatigue is offered on the basis of the recently announced micellar theory for the solid state. Illustrations are given.—INCO.

3.5.8, 1.6

The Fracture of Metals. Papers before Inst. of Metallurgists, Refresher Course, Ashorne Hill, Eng., Sept. 1949. Fracture of Metals, Jan. 1950, 138 pp.

Papers given at the refresher course included: Cohesion and Rupture in Metals by N. P. Allen, Fracture in Creep by R. W. Baily, Fracture Under Fatigue Conditions by H. L. Cox, Fracture Due to Stress Corrosion by U. R. Evans, Effects of Rate of Loading on Fracture of Metals by C. Gurney and Brittle Fracture in Mild Steels by W. Barr. Among the steels Cox used in his tests were, 3 nickel, 3-3½ nickel, 3½ nickel-chromium, 31½ nickel-chromium (embrittled) and nickel-chromium-molybdenum steels.—INCO.

3.5.9, 3.7.3

How Furnace Moisture Causes Embrittlement. C. A. ZAPPFE. *Iron Age,* **166,** No. 26, 60-65 (1950) Dec. 28.

Water vapor in heat treating furnaces has an embrittling effect on steel. The hydrogen potential of steam contacting steel at elevated temperatures exceeds the potential of pure hydrogen under theoretical pressures of hundreds or even thousands of atmospheres. Bend tests were used to confirm the steam-metal reaction theory. The bendability values are plotted for Types 414, 403, 410, 430 and 440-C stainless steels. Increasing carbon content rapidly increases the susceptibility of these steels to hydrogenizing. Atmospheres in the furnaces, failure due to steam, explanation of the hydrogen potential, relation of gassiness to silicon, high potential from the rust and the collection of atoms in voids are discussed.—INCO.

3.5.9, 6.2.6

Russians Have New Heat-Resistant Alloys. *Iron Age,* **167,** No. 12, 65-69 (1951) Mar. 22.

Shortages of nickel and cobalt in the USSR during World War II stimulated the development of the alloys of iron, chromium, and aluminum as a substitute for nickel chromium in electrical resistors and other high-temperature uses. Earlier researches, chiefly in Germany and the U. S., resulted in the development of some electrical resistor alloys. The best known of these alloys is Kanthal, containing up to 3 percent cobalt and manufactured in Sweden, and Smith Alloy No. 10, manufactured in the United States. Scarcity of nickel and cobalt restricted the wide use of Nichrome type alloys or alloys of the Kanthal type in the USSR. Considerable attention was therefore devoted to a study of ternary iron-chromium-aluminum alloys for electrical resistors. The most complete investigation was carried out by Kornilov and co-workers. Results of this work were published in book form by the USSR Academy of Sciences in 1945. These reports were translated by S. L. Case, Technical Advisor, Battelle Memorial Institute, who evaluated the significant data and compiled this article on the Russian's development. Kornilov's work covered the constitution, mechanical and electrical properties at various temperatures, scaling characteristics, and hot as well as cold-working properties of alloys containing up to 50 percent aluminum. The technology of the manufacture of the most promising alloys was also investigated. The allotropic transformation of iron-chromium-aluminum alloys is illustrated. The diagram indicates the existence of a closed gamma space bounded by the gamma loops of the iron-chromium and iron-aluminum binary system, and by the surface of the ternary solid solution. Phase diagrams derived from Kornilov's experimental data indicate that, under conditions of slow cooling, an aluminum content up to about 15 percent results in a single phase—a solid solution of iron-chromium-aluminum. In alloys quenched from 2100° F, the solid-solution structure is retained up to an aluminum content of 30 percent. Above this aluminum concentration, a new phase appears—the product of aperitectic reaction between the liquid phase and the ternary solid solution.—TDD.

3.6 Electrochemical Effects

3.6.1

The Importance of the Reactivity of Metal Surfaces in Electrochemical Reactions. (In German.) KURT WICKERT. *Metalloberflache, sec. A,* **4,** 181-186 (1950) Dec.

Presents theoretical analysis and critical discussion of existing theories concerned with the above, as an aid to the better understanding of corrosion problems. Includes diagrams, graphs, and tables.—BLR.

3.6.4, 4.6.11, 6.3.19

Studies of Time-Potential Changes on an Electrode Surface During Current Interruption—1-Zinc-Steel Couple in Synthetic Sea Water. S. SCHULDINER AND R. E. WHITE. Naval Research Lab. Paper before Electrochem. Soc., Buffalo, Oct. 11-13, 1950. *J. Electrochem. Soc.,* **97,** No. 12, 433-447 (1950) Dec.

A dc current interrupter method was developed for oscilloscopic studies of time-potential changes at an electrode surface during short interruption intervals. A variable length square pulse with a very short rise time and with a duty factor of approximately 1 percent was used to interrupt the current flow in a cell. Studies were conducted using interruption times from 1 microsecond to 120 microseconds. This interrupter technique permitted correction for the resistance error in closed circuit potential measurements. Polarization decay and build-up could be followed as the current was cut off and turned on, and the potential changes and double layer capacity effects occurring at an electrode surface during interruption could be measured. These phenomena were discussed in terms of an equivalent electrical circuit. An initial study of polarization phenomena on the zinc-anode-steel cathode system in a synthetic sea water electrolyte was carried out using this interrupter method. Illustrations. 17 references.—INCO.

3.6.6, 3.4.6

Formation and Electrochemical Reduction of Oxide Layers on Metals. (In German.) F. TODT. *Z. Elektrochem.,* **54,** 485-494 (1950) Oct.

Experiments on the above show that the current density of a galvanic cell (platinum cathode and unpolarized anode) is approximately proportional to the quantity of available oxygen. Similar results, obtained with mercury and copper show that the chemical reaction on cathodically polarized electrodes can be quantitatively determined by measuring the current density. Diagrams, graphs and tables. 12 references.—BLR.

3.6.6, 5.2.4

Some Electrical Relations in Galvanic Couples—PR 2148. H. D. HOLLER. *J. Res. Natl. Bur. Standards,* **45,** No. 5, 373-380 (1950) Nov.

The electrical relations are developed for a galvanic couple (short-circuited cell) with and without polarization by externally applied current. Their significance in the derivation of criteria for cathodic protection is demonstrated. The mechanism of current flow between couples at different potentials is explained. The importance of galvanic-couple theory in governing current distribution over an electrode surface is indicated.—INCO.

3.6.9, 8.4.3

Protection of Well Casings Against External Corrosion. R. E. HAMMOND AND S. P. EWING. *World Oil,* **132,** 154-156+ (1951) Feb. 1.

Describes investigation of leaks in the Loudon Pool, Illinois, caused by external corrosion by the Tar Springs formation, in which permeable saltwater sand overlays the producing zones. It was found that more than 90 percent of this corrosion was caused by electrolytic currents. To stop it, insulating nipples or flanges were placed between flow lines and casings. Records before and after insulators were installed indicate an ultimate saving for this group of wells of $1,700,000.—BLR.

3.6.9, 1.7.1, 5.1

Electrolytic Corrosion and the General Theory of Corrosion. 2nd Report of the Gas Works Safety Rules Committee. E. G. STEWART, A. G. PALMER, AND W. T. K. BRAUNHOLTZ. Institution of Gas Engineers, Copyright Publication No. 374, Nov. 1950, 43 pages.

Describes types of electrolytic corrosion and test procedures. Interprets results. Discusses practical mitigation of corrosion. Covers cast iron and carbon and alloy-steel pipe. 64 references.—BLR.

3.6.10, 5.4.5, 4.6.11

Electrochemical Behaviour of Paint Films in Sea-Water: A Suggested Mechanism. J. T. CRENNELL. *J. Soc. Chem. Ind.,* **69,** 371-373 (1950) Dec.

The cathodic character of painted or otherwise partially screened steel in seawater is explained by the retention behind the paint-film of the products of reaction of local corrosion couples. Local anodes behind the film will be suppressed by accumulation of ferrous ions. Alkalinity produced at local cathodes renders the steel passive and so encourages passage of further current in the same direction. Experiments are described showing that an iron electrode transferred from neutral to alkaline salt solution becomes temporarily anodic, then quickly becomes cathodic as passivity develops. 3 references.—BLR.

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before

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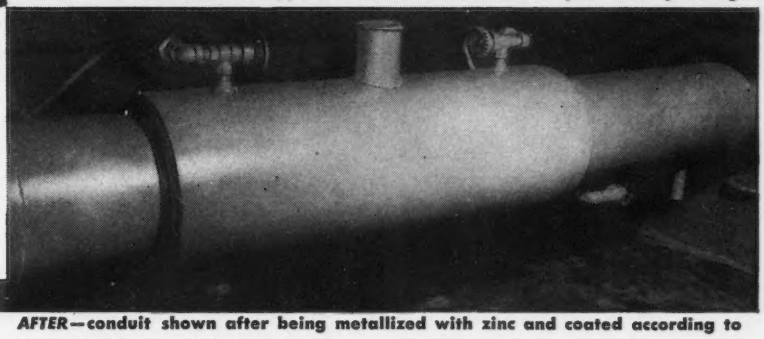

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3.7 Metallurgical Effects

3.7.2, 6.3.6

On the Improvement of the Imitation Gold. (In English.) TOSIHIKO OKAMURA AND TAKASI KIMURA. *Science Reports of the Research Institutes, Tohoku University*, ser. A., **1**, 473-478 (1949) Dec.

"Imitation gold" tarnishes upon contact with perspiration during use. Antitarnishing properties of ternary alloys of copper, zinc and aluminum, also effects of fourth elements upon them, were investigated. It was found that $\alpha + \beta$ alloy is generally the most resistant and that a slight addition of lead, iron, manganese, or silicon imparts tarnish resistance, while addition of silicon is followed by a remarkable increase of hardness.—BLR.

3.7.2, 6.2.2, 4.3.2

Corrosion Resistance of Cast Irons in Dilute Acids. (In English.) ICHIRO IITAKA AND KAZUHIKO SEKIGUCHI. *Repts. Casting Research Lab.*, **1950**, 4-6, Jan.

Presents results of experiments on effect of chromium content on acid resistance of cast irons and on effects of added metals on acid resistivity of high-silicon iron alloys.—BLR.

3.7.3, 6.4.2

The Effect of Surface Finish on the Stress-Corrosion Properties of Aluminum-7% Magnesium Alloy. S. E. HADDEN AND E. C. W. PERRYMAN.. BNFMRA. *Metallurgia*, **42**, No. 254, 392-396 (1950) Dec.

The stress-corrosion life of aluminum-7 magnesium alloy sheet in a susceptible condition is dependent on the state of the surface. Suitable surface treatments after aging, e.g., longitudinal emery, wet-blast, buffing or metallographic polish without etch can considerably increase the stress-corrosion life. The production of a magnesium-impoverished surface layer also causes an improvement. Series of tests and results are given. Tables. 9 references.—INCO.

3.7.4, 6.2.5

Sigma Phase in Stainless—What, When and Why. G. V. SMITH. US Steel Corp. *Iron Age*, **166**, No. 22, 63-68 (1950) Nov. 30; No. 23, 127-132 (1950) Dec. 7.

Coverage includes controversial mode of formation, importance of prior treatment, difficulty in identification of sigma effect on mechanical properties, occurrence of sigma in many alloys, stabilizers which increase sigma, how sigma weakens high-temperature strength, effect of sigma on corrosion and how sigma increases the corrosion rate. Sigma can be converted to harmless delta ferrite by heat treatment. However, this restoration method may produce grain growth. Graphs and microstructures are given. 17 references.—INCO.

3.8 Miscellaneous Principles

3.8.3, 6.3.4, 6.3.13

Isotopic Exchange Between Cobalt and Tantalum and Their Ions in Solution. (In French.) MAURICE COTTIN. *Compt. Rend.* (France), **231**, 697-699 (1950) Oct. 9.

Cobalt and tantalum were studied as important examples of passive metals or metals readily passivated. The surfaces were polished mechanically and electrochemically. Radioactive cobalt (Co^{60}) obtained from Oak Ridge and tantalum (Ta^{182}) from Harwell (England) were used in contact with series of salts of the metals. Conditions favorable or unfavorable to exchange as revealed by the results are summarized.—BLR.

3.8.4

Structure of Thin Films of Aliphatic Esters and Alcohols on Metals. J. V. SANDERS AND D. TABOR. *Proc. Royal Soc.*, ser. A, **204**, 525-533 (1951) Jan. 9.

Describes an electron-diffraction study of structure and orientation of the orientation of the above. Effect of temperature was also examined by transmission and reflection methods. Bearing of the results on nature of the disorientation process is discussed and they are compared with boundary-lubricating properties of the substances. 18 references.—BLR.

3.8.4, 3.6.5

Rate of Dissolution of Silver in Aqueous Ceric Sulfate Solutions. HUGH W. SALZBERG, HELEN KNOETGEN, AND ANN M. MOLLESS. *J. Electrochem. Soc.*, **98**, 31-35 (1951) Jan.

Presents results of experimental and theoretical study of the above. Shows that dissolution of silver and copper in ceric sulfate is diffusion controlled, in contrast to dissolution in ferric sulfate solutions, which is desorption controlled. By analogy with silver, reactions between oxidants and metals with small differences in standard oxidation potential should be desorption controlled and those with large potential differences should be diffusion controlled.—BLR.

4. CORROSIVE ENVIRONMENTS

4.2 Atmospheric

4.2.8

Collection and Analysis of Solids in Urban Atmospheres. J. CHOLAK, L. J. SCHAFER, AND R. F. HOFFER. *A.M.A. Arch. Ind. Hygiene and Occupational Med.*, **2**, 443-453 (1950) Oct.

Describes and illustrates methods and equipment used in investigation of atmospheric conditions in Cincinnati, with respect to certain solid constituents. Analysis is limited to particulate matter other than pollen and bacteria. It does not include determination of condensation nuclei as such, nor does it include more than a cursory examination of the dust for particle size and its distribution. Typical data are tabulated. 18 references.—BLR.

4.3 Chemicals Inorganic

4.3.2

Corrosion of Composite Electroplated Coatings. J. E. STARECK. Summary of paper presented to 97th meeting of Electrochemical Society. *Products Finishing*, **15**, No. 1, 44-54 (1950) Oct.

Discusses factors influencing corrosion of metal having outer and intermediate electrodeposited coatings. Rules governing the mechanism of the corrosion have been formulated.—BNF.

4.3.6, 3.4.6, 2.4.2

The Corrosion of Iron Covered by a Thin Film of Neutral Salt Solution. W. I. WHITTON. *Trans. Faraday Soc.*, **46**, Pt. II, 927-938 (1950) Nov.

The corrosion of iron covered by a thin film of neutral salt solution was examined. Work with .5 normal sodium chloride solutions and oxygen atmosphere is described. Four different low alloy nickel-chromium steels were used. Under these conditions, unusual results were obtained, due to the combined effort of the high electrical conductivity of the liquid film and the unrestricted supply of oxygen reaching the metal surface. These results are dependent almost entirely on the corrosion properties of the metal itself. They indicate that acceleration of corrosion of the "oxygen absorption" type may be caused by the catalytic effect of certain impurities and not necessarily of oxide films, on the oxygen depolarization action. Several of the results differ from those found for specimens corroding in a restricted supply of oxygen and the need for differentiation between these 2 types is indicated. A simple apparatus which may be of use for industrial testing was developed for this work. Illustrations, corrosion rate tables and 19 references are given.—INCO.

4.6 Water and Steam

4.6.2, 6.2.5

Mechanical Properties and Corrosion of Steel. J. GALIBOURG. *Chimie et Industrie*, **41**, 1939, Special Number, 168-178; 800-word abstract.

Occurrence of alkaline embrittlement. Calculations of structural parts on basis of corrosion fatigue limit. Occurrence of cracks in 22 percent nickel, 2 percent chromium steel under action of superheated system. Translation available Henry Brutcher, Box 157, Altadena, Calif.

4.6.6, 6.3.6

Corrosion Behavior of Very Dilute Aqueous Solutions. IV. Corrosion of Copper. (In German.) L. W. HASSE. *Werkstoffe u. Korrosion*, **1**, 390-393 (1950) Oct.

Discusses critically the theories of corrosion of copper by above solutions (including city water). Shows that warm water reactions with copper to form hydroxides, carbonates, basic chlorides, and sulfates of copper, which, however—because of their slight solubility—form mostly a protective coating on the copper. Traces of copper in water may deposit on other metals and cause galvanic corrosion. Effects of addition of other elements (arsenic, phosphorus, silver) are also discussed. 11 references.—BLR.

4.6.12

Water Conditioning for Oil-Field Flooding Operations. N. A. VOSS AND E. NORDELL. Permutit Co. Paper before ACS Symposium on Conditioning Water for Repressuring Oil Fields and for Underground Disposal, Houston, Texas. *Oil Gas J.*, **49**, No. 27, 174-177 (1950) Nov. 9.

The article contains a discussion of the types of water used in flooding operations. These include ground and surface waters and oil-field brines. Clogging substances and corrosion caused by dissolved oxygen, hydrogen sulfide and/or a low pH value are outlined. A discussion on processes and equipment for the

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As sheeting, TYGON is generally used as linings and coverings for tanks, tank covers, absorption towers, vats, bins, hoppers, troughs, blowers, impellers, fume hoods and fume ducts. In this form, TYGON is resistant to phosphoric acid in any concentration and at temperatures as high as 165-170°F. Where only fumes of the acid are encountered, the temperature limit can be raised to 200°F. Prolonged contact with mixtures of phosphoric and other acids, or organic compounds, is not advised without the previous counsel of U. S. Stoneware engineers.

TYGON sheets are also die-cut into gaskets, washers and diaphragms for use in pumps, valves, filters, reactors, piping and all types of process equipment. In such uses, chemical resistance is the same as with the linings. Temperature limits, however, may be somewhat higher, depending upon the size, design and specific use of the die-cut piece.

As molded goods, TYGON also finds use as gaskets and as grommets, washers, bumpers, handles, stoppers, closures, and miscellaneous parts and fittings. Here again, resistance to all concentrations of phosphoric acid is excellent and temperature limits may range up to 200°F or higher depending on the size, shape and use of the molded item. Combinations of phosphoric acid and other chemicals are best handled only after qualified advice.

In extruded form, TYGON is used primarily as tubing and piping with sizable quantities of solid cord and channel going into gasketing applications. Extruded TYGON also resists phosphoric acid in any concentration and at temperatures as high as 200°F. Mixtures of phosphoric and other acids, or organic compounds, is not recommended without engineering counsel. Where constant pressures of more than 40 psi are involved, particularly at elevated temperatures, braided jacket reinforcement is available and advised.

Typical uses of TYGON Tubing include all laboratory applications and many plant piping jobs. The clarity, flexibility, abrasion-resistance, smooth surface, and lightweight of the larger sizes (up to 2" ID) prove advantageous in such uses as transfer lines; as ports on pumps, filters and compressors; as syphon hoses; as line desurgers, and, as flexible connections.

For protective coating work, TYGON is available as a solvent type paint and as a plastisol (TYGOFLEX). Both forms are resistant to the fumes and spillage of phosphoric acid in any concentration and at temperatures up to 200°F for the paint and 250°F for the plastisol. Neither form should be exposed to mixtures of phosphoric acid and other chemicals without previous advice.

As a paint, TYGON is used to protect all types of equipment, structural steel, walls, and ceilings. Special consideration should be given to the limits of a thin film; but, in general, excellent service can be obtained by using a primer plus two top coats for mild environments and a primer with no less than five top coats for severe exposures.

As a plastisol, TYGON finds use as a heavy duty coating and in the casting or "slush" molding of flexible parts and fittings.

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removal of turbidity sediment, oil, iron, carbon dioxide, hydrogen sulfide, oxygen, calcium carbonate and calcium sulfate is given. Illustrations of equipment are given.—INCO.

4.6.13

Chemical Engineering Aspects of Industrial Wastes Control. C. Fred Gurnham. *Sewage and Industrial Wastes,* **23,** 82-88 (1951) Jan.

Discusses unit task concept, oxidation, reduction, neutralization, electrolysis, double decomposition, halogenation, ion exchange, other unit processes and unit operations.—BLR.

4.8 Other

4.8, 8.1.2

Influence of the Quality of Mortar and Concrete Upon Corrosion of Reinforcement. Rachel Friedland. *J. Am. Concrete Inst.,* **22,** 125-139 (1950) Oct.

In tests to determine influence of the quality of mortar and concrete upon corrosion of reinforcing steel, the variables studied were cement content, water-cement ratio, consistency, grading, and depth of cover. The specimens, stored in moist air or exposed to weather, were tested up to two years. Results indicate that consistency has a pronounced effect upon the protective value of mortar and concrete, and that there appears to exist an "optimum consistency" at which the quantity of rust is practically unaffected by time. It was also found that the usual cement contents in reinforced concrete have only a limited corrosion effect.—BLR.

5. PREVENTIVE MEASURES

5.1 General

5.1, 8.8.1

Cyanamids Corrosion Control. S. W. Shepard. *Industry & Power,* **60,** No. 1, 112-115 (1951) Jan.

The main philosophy followed by the Am. Cyanamid Co. in regard to corrosion is to design away from corrosive conditions. The various corrosion factors that are important in the company's plants are reviewed. These include stress corrosion cracking, temperature, aeration, agitation, local corrosion or pitting, corrosion inhibitors and cathodic protection. Tabulated data presented include much information on the effect of air on corrosion by oxidizing and non-oxidizing acids, the galvanic series of metals, efficiency of corrosion inhibitors in normal sulfuric acid, organic barriers to corrosion and the resistance of corrosion inhibitors to various agents.

5.2 Cathodic Protection

5.2.1

Cathodic Protection at Imperial Dam. J. P. Collopy and W. D. Freeman. U. S. Bureau of Reclamation. *Eng. News-Record,* **146,** No. 1, 43-44 (1951) Jan. 4.

A cathodic protection system was installed at Imperial Dam, located on the Colorado River, to prevent electrolytic deterioration of the heavy tonnage of metal installed at the structure. The protection work is intended to increase the period between applications of such protective coatings as paint and coal-tar enamel, thus minimizing maintenance costs. Aluminum alloy and carbon anodes are being used in the protection system.—INCO.

5.2.1, 7.2, 8.9.3

Cathodic Protection Has Paid Off in New Orleans. S. E. Trouard. New Orleans Public Service, Inc. *Gas,* **27,** No. 2, 59-61 (1951) Feb.

Severe corrosive conditions due to the acid muck have been overcome in the New Orleans gas pipe line system by means of cathodic protection. No failures have yet occurred in the system some of which has been in use since 1927.

5.2.2, 8.4.3

Cathodic Protection of Fourteen Offshore Drilling Platforms. E. P. Doremus and Gordon L. Doremus. Cathodic Protection Service, Houston. *Corrosion,* **6,** 216-224 (1950) July.

Corrosion of the one-half million square feet of submerged bare steel surfaces of fourteen offshore drilling platforms in the Gulf of Mexico has been practically eliminated by applying cathodic protection. This has been accomplished by initial application of a high current density of 50-350 ma per sq ft employing magnesium ribbon (Galvoline) to deposit a calcareous coating on the metal surface to be protected.

Total current requirements at high densities fall in the range of 6-10 amp-hr per sq ft. The electrocoating polarizes the surface and reduces current requirements for permanent corrosion protection to a value approaching 3 ma per sq. ft. This is supplied by means of sacrificial magnesium anodes, each weighing about 51 lb and capable of furnishing protective current for 600 sq. ft. for a period of 2 yrs. A sufficient number of anodes were installed to provide protective potentials of at least —9.78 v, preferable —0.90 v, referred to a saturated calomel electrode adjacent to the surface to be tested. The output of the anodes is adjusted to protect the platforms for 2-3 years.

The cost of applying cathodic protection to offshore platforms of average size for the initial 2-year installation amounts to 5-6 cents per sq. ft. per yr. including electrocoating costs. Average annual cost over a 10 year period may amount to as little as 4 cents per sq. ft. —PDA.

5.2.3, 5.4.5, 2.3.5

Some Factors Affecting Paint Performance on Cathodically Protected Steel. Arnold J. Eickhoff and David L. Hawke. National Lead Company Research Laboratories, Brooklyn, New York. Presented at Sixth Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo., April 4-7, 1950. *Corrosion,* **7,** No. 2, 70-74 (1951) Feb.

A discussion on the paper by W. L. Crosby, "The Use of Cathodic Protection in Conjunction with Paint Coatings —A Progress Report." Published in *Corrosion,* Vol. 6, No. 11, 383-388 (1950) Nov. Principles of cathodic protection are briefly described. The factor of increased alkalinity in the vicinity of the anode is the most significant product of an electrolyte. This alkali will spread beneath the film in paint at a holiday and lift it. Electro-osmosis also must be considered. Five types of paint were studied: 1) linseed oil; 2) alkyd resin; 3) modified chlorinated rubber; 4) air dried vinyl resin; 5) baked vinyl resin. They were chosen because of their recognized differences in alkali resistance. Steel panels partly immersed in 3 percent sodium chloride were either coupled through resistors with magnesium panels of similar size and shape are coupled in parallel with carbon rods with an external EMF making steel the cathode. Current imposed was 29 ma per sq. ft. and 500 ma per sq. ft. The data secured indicate there is correlation between alkali resistance and cathodic protection performance of paints.

5.3 Metallic Coatings

5.3.2, 2.2.2

Electrodeposits as Bases for Paints. H. Silman and D. Wernick. *J. Electrodepositors' Tech. Soc.,* **25,** 175-188 (1950).

In this paper, an attempt has been made to assess the value of electrodeposits as undercoats for paint on a basis of such tests as it has been possible for the authors to carry out. The results are in the nature of a preliminary survey. The paper is confined largely to electrotinned and electro-galvanized steel due to their increasing availability.—EL.

5.3.2, 2.3.9, 3.7.4

The Structure of Metal Deposits Obtained by Electrochemical Displacement Upon Zinc. M. E. Straumanis and C. C. Fang. *J. Electrochem. Soc.,* **98,** 9-13 (1951) Jan.

An attempt was made to identify the composition and structure of nonadherent immersion deposits of noble metals on zinc. For this purpose copper, gold, nickel and silver deposits, obtained by electrochemical displacement from their salt solutions in sulfuric acid, were examined by X-rays. All of them contained redeposited zinc. 25 references.—BLR.

5.3.2, 6.2.3

Sprayed Aluminum Coatings on Steel. G. Tolley. *Brit. Ind. Finishing,* **3,** No. 30, 377-380+ (1950) Dec.

Mechanism of protection. Results of field tests. Heat resistance.—BNF.

5.3.2, 7.1

Cadmium-Tin Alloy Plating Stops Corrosion. B. E. Scott and R. D. Gray, Jr. Wright Aeronautical Corp. *Iron Age,* **167,** No. 3, 59-62 (1951) Jan. 18.

Corrosion problems are serious ones in the manufacture and operation of aircraft engines. The reciprocating engine is particularly susceptible due to the low corrosion resistance of the steels normally employed. Extensive tests have led to the development of a successful cadmium-tin alloy plating solution. The deposit is obtained from a fluoborate solution, strongly acid (pH 2.5 to 3.0), and contains approximately 75 cadmium and 25 tin. The test panels prepared from SAE steel were plated in the cadmium-tin bath, then subjected to the salt spray tests. Good corrosion resistance was achieved. Tables. 5 references.—INCO.

5.3.4

Use of Aluminum in Hot-Dip Galvanizing. M. J. Hughes. *J. Iron Steel Inst.,* **166,** Part 1, 77-84 (1950) Sept.

A review is presented of the opinions expressed in literature on the subject of aluminum additions in hot-dip galvanizing, and experiments are described which were conducted to determine the mini-

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mum amount of aluminum needed to eliminate alloy layers (or to reduce these layers to an extent that adequate bending properties are obtained). Advantages claimed for aluminum additions in hot-dip galvanizing include improved luster, diminished rate of bath oxidation, increased corrosion resistance of coating and elimination of the usual iron-zinc alloy layers. This latter advantage, obtainable with heavier aluminum additions, is the most important, since it has a marked effect on the bending properties of the material. Fluxing difficulties are discussed and theories which are advanced to explain the action of aluminum in producing alloy-free coatings are reviewed. In connection with the above mentioned experiments (to determine minimum amounts of aluminum required to eliminate alloy layers), four steels were tested under various dipping conditions. This work was limited to shorter than usual immersion times and to a normal range of operating temperatures. Current theories on the mechanism by which alloy-free coatings are produced from baths containing aluminum are shown to be incorrect. It was found that, under suitable conditions, an alloying process different from the normal one may occur.—TDD.

5.3.4, 7.2, 8.2.1

Metal Spraying of Power Station Waterpipes. *Ind. Finishing,* **3,** No. 26, 71-72 (1950) Aug.

A brief description of a demonstration of sand blasting, zinc spraying and painting of water circulating pipes, given at Carrington Power Station, Manchester. Both the interior and exterior surfaces of the pipes are given an 0.006 in. coating of zinc by the powder process after roughening. They are finished with one coat of zinc chromate primer and two of bituminous paint. After the pipes have been welded together, a mobile unit touches up the joints.—ZDA.

5.4 Non-Metallic Coatings and Paints

5.4.2, 7.2, 3.6.9

The Disintegration of Concrete Pipe Coatings. *Oil & Gas J.,* **49,** 45, 52 (1951) Mar. 15.

The disintegration of concrete pipe coatings resulting from galvanic-cell action set up between concrete-coated steel pipe and bituminous-coated pipe was explained by D. Hendrickson at the Pacific Coast Gas Assoc. Meet., Los Angeles (3/7-8/51). He recommended draining off of any stray current on a concrete-coated pipe and the use of insulated joints located as near as practical to the boundaries of different types of soil, when inter-connecting to pipe lines having coatings which might create a galvanic cell.

5.4.2, 6.4.2

The Protection of Optical Glass and Aluminum-Surfaced Mirrors. Flamant. *Journal de physique et le radium* (France), **11,** 380-384 (1950) July. *Science Abstracts* (England) A, **53,** No. 635, 947 (1950) Nov.

The object of this study is the behavior of films as used for increasing or decreasing the reflectivity of glass, and of films likely to be used for protection of metallic deposits, when they are exposed to an atmosphere containing sea-air, at a temperature of 35° C (95° F), during a time sufficient to cause deterioration. The fluorides used either as protecting films or for anti-reflection treatment, have a poor resistance, magnesium fluoride giving the best results, but being practically destroyed after about 10 days. Silicon and especially silica are practically unalterable when deposited on glass. They give by far the best protection for reflecting surfaces of metallic aluminum. But this protection disappears eventually owing to breaking of the protective layer which forms an increasing number of fissures through which the attack of the subjacent metal takes place. The difficulty is apparent with all the substances deposited on metal, and in particular with titanium dioxide. Aluminum films of sufficient thickness obtained under very good conditions of vacuum and cleanliness, on which the natural protective aluminum oxide film is formed by exposure to air for one month show good resistance also. Processes of rapid formation of the protective film of aluminum oxide by chemical means have given moderate results.—ALL.

5.4.2

Inert Coating. *Chem. Eng.,* **58,** No. 1, 164 (1951) Jan.

Metl-Kote has to date weathered more than 2 years of salt brine tests without permitting any corrosion to steel surfaces. When applied to wood or steel surfaces it will not support combustion, flash nor burn. It is recommended for such things as army tanks and navy ships where the above properties would be desirable. Manufactured by Corrosion Engineering Co.—INCO.

5.4.5, 1.3

Silicone Resins in the Protective Coatings Industry. I. W. Hutchison. *Am. Paint J.,* **35,** 80+ (1951) Feb. 5; 62, 64, 66, 68-69 (1951) Feb. 12.

Reviews chemistry, properties and applications. Includes test-panel photographs and tables.—BLR.

5.4.5, 8.3.5

Problems and Practice of Lacquering Preserving Cans. H. E. Scheiber. *Farbe u Lack,* **55,** No. 10, 370-372; No. 11, 409-411 (1949); **56,** No. 2, 59-61; No. 3, 103-105 (1950).

A general survey of the field is given with particular reference to effecting a compromise among the desirable properties of lacquer coatings. The merits of stoved coatings and the relation of stoving conditions to mechanical properties are emphasized. Tastes and odors may be removed by adjustment of stoving conditions. Mechanical properties (adhesion, flexibility, and ability to withstand stamping) may, however, be adversely affected thereby. Since a canned food product may react with a lacquer film, the toxic nature of the film constituents must be carefully considered; lead driers are accordingly not used in lacquers for food cans, but the use of 1-2 percent zinc oxide in sulfur-resisting lacquers is not considered dangerous. The concept and control of porosity with stoved coatings is considered.—RPI.

5.4.5, 1.4

Protective Coatings on Metals. Bibliographic Series No. 14. F. D. Horrigan and C. R. Sage. Technical Library, QM Research & Development Labs., Philadelphia. Available from O.T.S. as PB 102172. Oct. 1950. 55 pp. $1.50 (TA-468, T-25).

One hundred and seventy-seven patent and literature references from 1941 to date on protective coatings of metals are included. Special emphasis is on corrosion protection and author, inventor and patent number indices are appended.

5.4.5

Mildewing of Paints and Its Prevention. Richard E. Vicklund and Milton Manowitz. *Paint and Varnish Production Mgr.,* **31,** 8-11, 26 (1951) Feb.

An illustrated survey. 12 references.—BLR.

5.4.5

Surface Coatings in the Protection of Plant. J. C. Towner. *Paint Notes,* 5, No. 9, 250-253 (1950).

The composition of modern paints, especially those required to protect against corrosion, is discussed. Safflower oil, as a component of oil paints and chlorinated rubber are two novel media which are much used in Australia. Bituminous coatings possess outstanding resistance when intact; phenol/formaldehyde/tung oil formulations have satisfactory alkali resistance but chlorinated rubber is better. Pure thermosetting phenolics may be the answer to very corrosive environments.—RPI.

5.4.5

Corrosion Protection Through Paints in the Bitumen Industry. E. Sachse. *Bitumen, Teere, Asphalte, Peche,* 1, No. 11, 297-299 (1950).

A discursive article on industrial paints (mostly non-bituminous), their composition and application, particularly for the protection of iron and steel.—RPI.

5.4.5

Metal Protective Red Lead Paints. C. J. Vander Valk. *Paint and Varnish Production Mgr.,* **31,** 8-13 (1951) Jan.

Presents typical specification formulas, describes properties and gives exposure-test results in contact with different atmospheres and liquids.—BLR.

5.4.5

Functions of Pigments in Corrosion Prevention. C. H. Z. Woinarski. *Paint Notes,* **5,** No. 9, 253 (1950).

The ways in which pigmentation of a protective coating assists in preventing metal corrosion are discussed.—RPI.

5.4.5

Wear Resistance of Paints. H. W. Talen and N. A. Brunt. *Verfkroniek,* **23,** No. 9, 236-238 (1950).

A series of 8 paints similarly pigmented, but based on different media, were compared by applying them to floorboards at an exit to Amsterdam Central Station, over which 40,000 passengers passed per day and observing the condition of the paint at periods up to nine days. Failure occurred by gradual abrasion and by peeling off through lack of adhesion. The order of merit from best to worst of the 8 media was: dehydrated castor oil (45 poise stand oil)/modified phenolic resin (2:1), air-drying alkyd (25% phthalic anhydride), linseed stand oil/modified phenolic resin (2:1), tung oil/pure phenolic resin (2:1), chlorinated rubber/chlorinated diphenyl (4:3), cyclised rubber/chlorinated paraffin wax/linseed oil (20:2:1), N. C./maleic resin/dibutyl phthalate (10:5:6), N. C./non-drying alkyd (1:1).—RPI.

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5.4.5
Vinyl Butyral Resins for Anti-Corrosion. Union Carbide & Carbon Chemical Corp. *Food*, **19**, No. 228, 349 (1950).

Two formulae for wash primers are given. The primers contain a chrome pigment and vinyl butyral resin in addition to aqueous phosphoric acid. The presence of the resin is advantageous where ferrous or non-ferrous metals come into contact with solvents or oils. Substantial protection against corrosion of steel is afforded by the wash primer coat alone.—RPI.

5.4.5
Thermoplastics for Temporary Mechanical Protection of Materials and Equipment. E. E. HALLS. *Plastics*, **15**, No. 153, 48; No. 154, 74-77; No. 155, 102-105; No. 156, 142-144; No. 159, 215-216 (1950).

The use of easily strippable plastic coatings to prevent articles being damaged by corrosion or much handling during transit is described. The treatments described include hot-dipping, spraying and cocoon packing; details of technique and materials used are given. —RPI.

5.4.5
A New Corrosion and Rust Control Material. *Oil Paint Drug Reptr.*, **159**, No. 7, 45 (1951) Feb. 12.

A new corrosion and rust control material for almost the entire range of porous and non-porous basic materials, said to have excellent lubricating properties, has been developed by American Sand-Banum Co. "Tinallium Pro-Tex-It" is a non-drying black paste and offers protection against rust, corrosion, oxidation, heat, cold, steam, gas or sulfur fumes, brine and other destructive agencies either above or below ground.

5.4.5, 7.7
Tropicalisation of Radio and Radar Equipment. A. R. CLOSE and Others. U. S. Air Material Command, Contract AF-33-(038)-450, 1949, 146 pp. *Prev. Det. Abs.*, **7**, E81 (1950).

The most effective coatings for tropicialising radio and electronic communications equipment are varnishes based on p-phenyl-phenol/formaldehyde resins with 8 percent salicylanilide added as a fungicide.—RPI.

5.4.5
Aluminum Coating. *Chem. Eng. News*, **28**, No. 50, 4382 (1950) Dec. 11.

A development in metal protective coatings, as tested by the Aluminum Company of America and the National Lead Company, is the combination of aluminum pigment with potassium-barium chromate. Innox-Aluminum, manufactured by the Richmond Marine Compositions Company, is a rust-inhibitor, due to soluble chromates; and a weather resistant finish coat, due to its high aluminum content. It can be used on ships' hulls, decks, superstructure, machinery and on structural steel, as a shop and field coat.—ALL.

5.4.5
Petrolite Wax Amines, A, B and C. *Chem. Eng. News*, **29**, 1121 (1951) Mar. 19.

Petrolite Wax Amines A, B and C are available in sample quantities from Petrolite Corp. Ltd. for possible use as corrosion inhibitors water-proofing agents, anti-static waxes and fungus- and mildew-proofing agents. Properties are listed.

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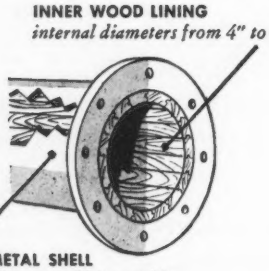

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5.5 Oil & Grease Coatings

5.5.2, 5.4.5
Corrosion Prevention. D. CLAYTON. *Chem. Trade J.*, **127**, No. 3316, 1431 (1950).

The prevention of corrosion of metal articles during handling and storage is discussed with reference to solvent-deposited soft films (e.g. greases) and hot-dip strippable coatings.—BNF.

5.5.3
Method for the Evaluation of Soft-Film Temporary Corrosion Preventives for Ferrous Articles. T. P. HOAR AND G. C. SMITH. Symposium on the Testing of Temporary Corrosion Preventives. *J. Inst. Petroleum*, **36**, No. 319, 448-457 (1950).

A very thin, but reproducible, film of preventive is deposited from a volatile solvent on to a clean steel surface, and the incidence of corrosion due to small drops of distilled water is determined after 24 hours. Reproducibility of results within an experimental run is excellent and the relative protective values of soft films based on mineral jelly and lanolin are tabulated. Reproducibility among experiments is much less than within experiments.—RPI.

5.6 Packaging

5.6.2, 8.6.3
Spray Packaging of Machinery. F. HOWLETT. *Brit. Rayon and Silk J.*, **26**, No. 312, 66-67, 85 (1950).

Spray processes for completely covering assembled machinery with a removable non-contacting film are described and illustrated, with special reference to the packaging of hosiery-manufacturing equipment for protection against atmospheric corrosion during storage or transport. Corrosion-inhibitive conditions inside the package are achieved by inclusion of suitable desiccants. Approximate costs are briefly discussed.—MA.

5.8 Inhibitors & Passivators

5.8.2, 8.9.2, 4.3.6
Control of Corrosion by Salt Used for De-Icing Highways. JOHN A. TEMMERMAN AND AARON STERLIN. *Corrosion*, **6**, No. 12, 391-393 (1950) Dec.

Describes cooperative program which resulted in development of a polyphosphate nitrite-base inhibitor. Laboratory tests indicated it was effective in controlling corrosion by salt brines. Weight-loss data on mild-steel panels are given as a function of inhibitor and salt concentrations. Experiences of Rochester, N. Y., using the above inhibitor incorporated in rock salt, are discussed.—BLR.

5.8.3, 4.3.2, 6.2.3
Substituted Amines as Inhibitors in the Acid Corrosion of Steel. L. E. SWEARINGEN AND A. F. SCHRAM. *J. Phys. Colloid Chem.*, **55**, 180-187 (1951) Feb.

The inhibiting action of ethylamine and of four of its substituted derivatives in the corrosion of steel cathodes by 1.0 normal sulfuric acid solution was studied. The derivatives were all, to varying degrees, better inhibitors than the parent compound. The increased inhibiting effect was not due to the size or shape of the inhibiting substance, but to those factors that are altered in such manner as to enhance adsorbability. 20 references.

5.8.3.
Dichromate Reduction Rate at a Steel Surface in Air-free, Acetic Acid Solution. N. HACKERMAN AND R. M. HURD. Univ. of Texas. Paper before Electrochem. Soc., Buffalo, Oct. 11-13, 1950. *J. Electrochem. Soc.*, **73**, No. 2, 51-56 (1951) Feb.

A system was devised in which aqueous solutions of potassium dichromate and of acetic acid could be brought in contact with steel coupons in the absence of air. The rate of reduction of the dichromate was determined as a function of time by titration and spectrophotometrically. Changes in pH were also followed. Rates were measured with various initial concentrations of dichromate and of acetic acid and for several areas of steel surface. The effects of temperature, presence of sodium chloride, presence of oxygen, and order of adhesion of the solutions were studied. There was measurable loss of dichromate in all cases except those in which air was deliberately added. In general, the rate curves become level before all of the dichromate was reduced, with maximum loss about 60 percent. It was concluded that dichromate at 400 ppm was a fairly effective inhibitor to the corrosion of steel down to pH 3.0 in the absence of oxygen even with 1000 ppm sodium chloride present. A mechanism for the reaction and of the corrosion inhibition is proposed. 9 references.—INCO.

5.9 Surface Treatment

5.9.1, 1.3
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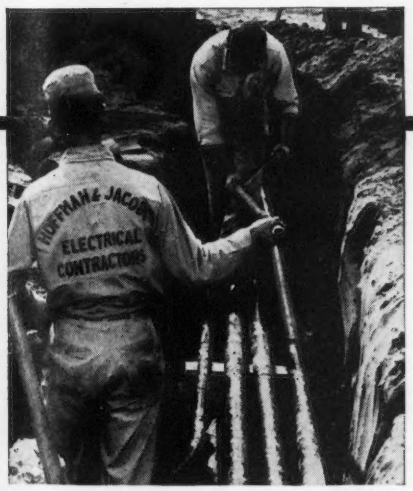

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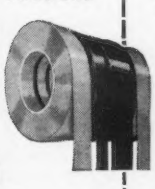

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1929. S. WERNICK. *Metallurgia,* **42,** No. 253, 339-344 (1950).
A review.—MA.

5.9.2, 6.3.10
The Use of Monel in the Pickling of Steel. Illus. booklet from Henry Wiggin & Co., Ltd., Birmingham. *32* pp.
Descriptions are given of the mechanism of pickling, types of pickling plants and pickling equipment. Monel metal may be used for tie-rods in wooden pickling tanks and for the many different types of cradles and lifting equipment for handling a wide range of goods. Many such crates are illustrated by drawings and photographs.—ZDA.

5.9.2, 8.9.1
Finishing Military Aircraft, Part I. Metal Cleaning. Gilbert Close. *Ind. Finishing,* **27,** 26-28, 31-32+ (1951) Jan.
Presents descriptive review of procedures for the above. Covers steel, brass, bronze, zinc, aluminum, magnesium, etc.—BNF.

5.9.2, 6.2.5
Scale Removal Technique with the Stainless Steels. L. F. SPENCER, LANDERS, FRARY AND CLARK. *Steel Processing,* **36,** No. 12, 623-628 (1950) Dec.; **37,** No. 1, 28-30 (1951) Jan.
Scale removal methods for stainless steels which would be involved in cold working operations. Mechanical and chemical methods of scale removal and equipment are discussed. A list of 11 pickling solutions, their compositions and operating temperatures, is included. Steel, stainless steel, concrete or wooden tanks are used, according to the solution utilized. With a ferric sulfate-hydrofluoric acid bath, the outer shell of the tank may be made of welded carbon steel plate lined with tellurium-lead. Graphs are given for the pickling time for scale removal on 302 stainless, optimum concentrations of baths for pickling 18-8, and metal loss in various solutions for 18-8. Experimental work on the ferric sulfate-hydrofluoric acid bath, the operation of a commercial bath, method of chemical analysis for ferric and ferrous sulfate and hafnium, the preparation of standard solutions and passivation are discussed. 8 references.—INCO.

5.9.2
Molten Salt Descaling. H. CLARK SMITH, JR. *Wire and Wire Products,* **25,** 1050-1051+ (1950) Dec.
Describes experiences of Wilbur B. Driver Co., Newark, N. J., in the setting up and the operation of a molten-salt cleaning bath for descaling of stainless steels and high-nickel chromium alloys. —BLR.

5.9.2, 5.4.2
Report on the Cleaning of Sheet Metal Prior to Vitreous Enameling. *Sheet Metals Inds.,* **28,** 89-94 (1951) Jan.
Describes experimental work on electrolytic cleaning; emulsion spray cleaning; effect of additions of surface-active agents to the ground-coat slip; phosphate coating; relation between chemical constitution and ageing; and grease burning for cleaning. Appendixes cover alkaline cleaning and degreasing before vitreous enameling; trichlorethylene degreasing before vitreous enameling; high-temperature grease burning and acid scaling of sheet iron before vitreous enameling; experiments with phosphate coating; and degreasing and enameling tests on standard cups.—BLR.

5.9.2
Paint Removal. *Ind.-Lack.-Betrieb,* **17,** No. 1, 10-12 (1949).
The removal of paint by mechanical means, burning off, treatment with caustic alkalis or treatment with solvents is discussed, the advantages and limitations of each process being outlined. Boric acid in alcoholic solution mixed with, e.g., carbon tetrachloride and benzine or benzene is used in paint removers for stoved films.—RPI.

5.9.2, 2.3.2, 6.2.5
How to Reduce Pickling Brittleness in Stainless Steels. CARL A. ZAPFFE. *Materials & Methods,* **32,** 74-77 (1950) Nov.
In a previous article (Oct. 1950), the fundamental nature and causes of embrittlement in steel due to acid pickling were explained. In this article, practical application of this knowledge to the avoidance or reduction of pickling brittleness is described. Discusses use of pickling inhibitors, surface-active agents, a foaming compound (negative results) and molten-caustic pickling. Also considers at some length the ageing and recovery process for removal of hydrogen from steel.—BLR.

5.9.2, 2.3.2
Surface Active Agents and Pickling Brittleness. CARL A. ZAPFFE AND M. ELEANOR HASLEM. *Wire and Wire Products,* **26,** 127-133 (1951) Feb.
Continuing a series of researches on embrittlement of steel caused by adsorption of hydrogen during acid pickling, the present study considers effects of bath additions other than pickling inhibitors—specifically the so-called surface active agents—also a foaming compound. Measurements of bendability using a specially designed wire bend test were used to follow quantitatively the changes produced by each reagent, alone and in combination with inhibitors in a standard 10 percent sulfuric acid bath.—BLR.

5.9.2
The Role of Spray Pickling in Porcelain Enamelling. J. W. ZANDER. *Better Enamelling,* **21,** No. 8, 6+ (1950).
In America, several porcelain enamelling plants are using a relatively new process known as spray pickling. Although in an early stage of development, spray pickling has been shown to have a definite place in both the plating and enamelling industries and with suitable plant modifications it could replace immersion pickling with advantage, raising production and lowering finishing costs. The spray method can be incorporated more easily into a continuous process than the immersion method, but at the moment, more operating experience is needed to achieve certain design changes necessary for better metal surface preparation by the spray pickle method.
In order to avoid excessive solution carry-over, the installation of running spray water rinses between all stages is necessary. This method minimizes oxidation, especially if the temperature is kept as near room temperature as possible, and the use of neutralizer cyanide solutions with flooding types of nozzles may prove more efficient than impingment sprays.
Considering the limitations of the process as a whole, from an unbiased viewpoint, it can be seen that spray pickling is a step in the direction of better metal surface preparation.—BLR.

5.9.2
Sulphuric Acid Cleaning and Coating of Rod and Wire in a Straightline Operation. R. H. HERTZOG. *Wire and Wire Products,* **25,** 1047-1048, 1079-1082 (1950) Dec.
Describes procedures and equipment of John A. Roebling's Sons Co., Trenton, N. J. Material processed is carbon steel.—BLR.

5.9.2
Detection of Soil Removal in Metal Cleaning by the Radioactive Tracer Technique. J. C. HARRIS, R. E. KAMP AND W. H. YANKO. *J. Electrochem. Soc.,* **97,** 430-432 (1950) Dec.; *ASTM Bull.,* **158,** 49 (1949).
Above technique was used to define apparent limits of sensitivity of the water-break, fluorescent-dye and copper-plate methods for the above. Quantitative estimates of limits of sensitivity are given.—BLR.

5.9.2
Improved Radioactive-Tracer Carrier for Metal Cleaning Studies. J. C. HARRIS, R. E. KAMP, AND W. H. YANKO. *ASTM Bull.,* **170,** TP 308-309 (1950) Dec. (See also NSA 3-328.)
This paper discusses the use of an oil-soluble tracer compound which is not chemisorbed and compares the results with those obtained using N,N-di-n-butyl stearamide. The compound chosen for this work was n-undecane since this was synthesized fairly readily by usual laboratory techniques to include an atom of and carbon isotope C^{14}.—NSA.

5.9.2
Improved Finish Through Better Surface Cleaning. J. C. HARRIS. *Canadian Metals,* **13,** 41-42, 44-45 (1950) Dec.
Discusses various methods (mainly chemical) for removal of submicroscopic surface films from metals. Also discusses methods for evaluation of quality of the cleaning job. 13 references.—BLR.

5.9.4
"Bonderizing" Equipment and Processes for Paint Adhesion. M. REEVES. *Metal Ind.* (London), **78,** No. 1, 7-8 (1951) Jan. 5.
"Bonderizing" surface treatment for metals produces a base for paints by converting the natural surface of the metal into a non-metallic phosphate coating. This coating has a velvety appearance, a crystalline and absorptive structure and excellent corrosion inhibiting properties. The "Bonderite" coating increases the adhesion and permanency of any paint finish because of a) the chemically clean, grease-free surface for all air drying paints and stoving pigments; b) the corrosion inhibiting surface over the whole workpiece; and c) the non-conducting bond between the base metal and the applied paint. A chemical process, "Bonderizing" can be applied to all metal surfaces using one of six available solutions. The two principal methods of carrying out the process are by immersion using standard solution, or by spraying using the "Spra-Bonderizing" process with special solutions. A special cold "Bonderizing" solution is now available which can be applied with an ordinary spray gun at normal pressures. The "Bonderizing" process is simple to operate and requires no skilled labor. The phosphatizing solution remains

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serviceable indefinitely and requires only an addition of the "Bonderite" chemical from time to time. The process was developed specially for light sheet metal work and a special process is designed for aluminum articles by which the components, after final rinse and oven dry, are in the ideal condition to receive paint and can be subsequently stoved up to 300°F. (148°C.).—ALL.

5.9.4, 5.9.3, 6.4.2

Relation Between the Continuity of Oxide Films and the Cleaness (Roughness) of Aluminum Surfaces. A. V. SHREIDER. *J. Phys. Chem.* (U.S.S.R.), **24,** 455-458 (1950).

Corrosion resistance of aluminum anodically oxidized in 3 percent chromium trioxide was severe for polished metal (average height h of asperites 0.28μ), less for ground (h 2.4μ), and least for sand blasted metal (h 5.6μ); two aluminum alloys showed analogous behavior. The weight loss during anodizing increased with roughness. Anodizing in chromium trioxide solutions (3-9 percent) increased h of polished aluminum by 0.025-0.5μ, while anodizing in 20 percent H_2SO_4 and in 5 percent oxalic acid $(COOH)_2$ increased it by 0.15-0.9μ; the current density was 0.6-3.5 amp. per sq. dm., voltage was 10-40 and duration of test was 15-40 minutes. The potential V of polished aluminum anodized in 20 percent H_2SO_4 was not very different from that of non-anodized aluminum because the oxide film on the rough surface was not continuous, while anodizing in 3 percent chromium trioxide (which raises h but slightly) shifted V by 0.25 v. Anodizing of sandblasted aluminum in chromium trioxide had but little effect on V.—ALL.

5.9.4

A New Way in the Field of Cold Phosphating. A. FOLDES. *Korrosion & Metallschultz,* **19,** 281 (1943).

Experimental study of performance of cold phosphating baths (67°-77° F) . . . Determination of pH most favorable for phosphate coating, in baths of different compositions. Sodium fluoride as buffer substance and its effect on corrosion resistance of coating. Recommended cold phosphating baths. Translation available Henry Brutcher, Box 187, Altadena, Cal.

5.9.4, 6.4.4

Surface Protection of Magnesium. J. S. KIRKPATRICK. *Modern Metals,* **6,** No. 11, 36-38 (1950) Dec.

Experience at Brooks and Perkins has revealed that the protection of magnesium is simpler than usually believed. Proper cleaning, which is an important prerequisite, is usually accomplished by an alkali soak for 15 minutes in a 10 percent solution of caustic soda maintained at 200°F. (93°C.). Wiping removes most of the graphite lubricant and immersion in a chromic bath for 30 seconds to 3 minutes at room temperature removes all graphite and all oxide. Magnesium is treated most commonly with the chrome pickle process followed by a good paint system or wax to provide added protection against atmospheres. Zinc chromate primers have been very successful especially AP-10 which has undergone salt spray and adhesion tests with good results. Electroplating of magnesium is also being perfected. Particular care must be taken to prevent galvanic corrosion of magnesium. It is avoided by treating all faying surfaces with a coat of zinc chromate primer followed by a coat of aluminum lacquer. When another metal is used next to magnesium, it is plated, usually with zinc or cadmium and given a phosphate or chromate finish. When severe tests must be withstood, further insulation with 0.032 zinc chromate tape or compound is recommended. Most coating failures are due not to the magnesium or the coating, but to operational carelessness.—ALL.

5.9.4

Iron Oxide Layer Obtained by the Dewozet Process as a Ground for Paints. H. KETTERL. *Fette u. Seifen,* **52,** No. 1, 38-41 (1950).

The Dewozet process for controlled oxidation of an iron surface, to secure a hard, elastic, firmly adherent oxide layer suitable as a ground for painting, is described. The iron surface is treated with diluted sulfuric acid for a few minutes, left in the air for a short while until an oxide layer forms, then heated to 200°.—RPI.

5.9.4

Treatment of Metal Surfaces before Painting. *Metalloberflache,* **4,** No. 7, 108-110 (1950). *Electroplating,* **3,** No. 16, 628 (1950).

Substances which cause poor adhesion of paint (e.g., rust, dirt, alkalies, detergents, etc.) may be removed from metal surfaces by a scheme, given in detail, which involves treatment with phosphoric acid preparations followed by mixing with water and washing in a neutralizing bath containing phosphoric acids at pH 3-5.—RPI.

5.9.4

Phosphate-Treated Surfaces as a Base for Painting. K. KALPERS. *Ind.-Lack.-Betrieb,* **17,** No. 12, 193-195 (1949).

The advantages of the phosphate treatment of steel surfaces before painting are outlined.—RPI.

5.9.4, 5.3.2

Corrosion Resistance of Chromate Treated Zinc Plating. C. W. OSTRANDER. *Plating,* **37,** No. 12, 1271 (1950) Dec.

In answer to a reader's query, it is stated that a clear chromate film on zinc plating generally withstands the salt spray test for 72 to 100 hours, depending on whether or not a clear stoving lacquer has been superimposed. Though 0.0002 in. of zinc is considered satisfactory for refrigerator racks, chromating delays the appearance of white corrosion products longer on zinc which is 0.0007 in. thick. Further increases in the thickness make little difference. The success of this method of protecting steel is said to depend very much on the care with which the process is carried out.—ZDA.

5.9.4

"Chromizing"; Details of a Process for Forming Chromium-Rich Layers on Steel. PHILIPPE GALMICHE. *Sheet Metals Inds.,* **27,** 749-750 (1950) Aug. Translated from *Recherche Aeronautique,* **1950,** Mar.-Apr.

Describes a simplified gaseous cementation method forming smooth composite diffusion alloys which may contain, in addition to chromium, elements such as silicon, aluminum or zirconium. These surface alloys are highly resistant to oxidation, deformation and thermal shock.—BLR.

5.9.4, 6.2.2

The Anodic Oxidation of Aluminum and Its Alloys. R. SEGOND. *Rev. Gen. Mecan.,* (N.S.), **34,** No. 20, 323-325 (1950).

A number of general recommendations are made on the selection of the most satisfactory types of aluminum alloys for anodizing to produce electrically insulating, decorative, or wear- and corrosion-resisting films. The control of the anodic treatment is also briefly considered.—MA.

5.9.4

Chemical Scuff Resistant Coatings for Ferrous Parts. GEORGE BLACK. *Product Eng.,* **20,** No. 4, 138-141 (1949) Apr.

Of various surface treatments for the prevention of scuffing, the phosphate coatings, especially that produced with manganese iron phosphate are apparently the most effective. The manganese iron phosphate coating is economical and easily applied. Assigning a scuff-resistance ratio of 1.00 to untreated case hardened gears, direct scuffing tests gave ratios of 2.05-2.10 for manganese iron phosphate, 1.36-1.69 for zinc phosphate coatings, 1.29 for caustic sulfur treated gears, 1.21 for colloidal graphite coatings and 1.00 for electroplated tin.

Manganese iron phosphate coatings are produced by immersing for 15-20 min. precleaned, degreased parts in a proprietary solution of ferrous and manganese dihydrogen phosphates maintained near 210°F., rinsing in hot running water and dipping in a water soluble oil for 30-45 sec. With suitable accelerators and oxidizing agents 2-5 minutes of immersion is sufficient and with a special spraying technique 5 seconds is sufficient.

The thickness of manganese iron phosphate films depends on method of cleaning and the type, hardness and surface finish of the base materials. Coatings thicker than 0.0004 in. cannot be produced.

The manganese iron phosphate treatment removes almost completely the burrs resulting from machining and polishing of the metal surface; thus in addition to reducing wear, it also lowers the cost of mechanical cleaning and other surface finishing operations. The phosphate coating increases surface lubrication because it has a high affinity for oil and because its porous surface acts as an automatic reservoir. The phosphate coating also prevents metal-to-metal contact during break-in periods.

This treatment is satisfactory for cylinder liners, pistons and piston rings, valve tappets, rocker arms, pulleys, camshafts, gears, sliding clutch gears, idler pinions and differential spiders. It prevents scoring when inserting hardened pins in such parts as forged I-beams and knuckles.

Phosphate coatings are also used to facilitate deep drawing and extrusion of steel.—PDA.

5.9.4

The Bonderizing Process. M. REEVES. *Mech. World,* **128,** No. 3324, 298 (1950) Sept. 29.

A short account of this proprietary phosphate treatment which may be applied to zinc and cadmium surfaces and to zinc alloy die castings to provide a base for subsequent painting. The phosphate coating, which exhibits corrosion-inhibiting properties, may be applied by immersion or by spraying or by a combination of the two methods.—ZDA.

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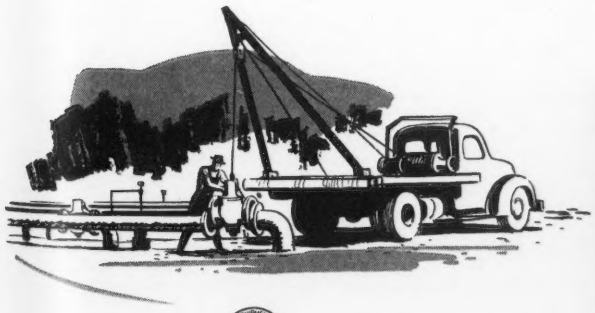

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5.9.4

Surface Protection via Phosphate Coatings. M. G. CRANDELL. Parker Rustproof Co. *Can. Metals,* **13,** No. 11, 30-31+ (1950) Nov.

Discussion includes Bonderite, why Bonderite protects metal surfaces and provides a better paint base, why the Bonderite coating retards the spread of rust, application of Bonderite, Spra-Bonderite for speed and mass production, Bonderite 170-a phosphate coating for aluminum and its alloys, Bonderite on zinc surfaces as a base for paint finishes, Bonderite as an aid in drawing either steel or aluminum, the Parco Compound and the Parco Lubrite. Parco compound provides a scientific method of effective rust prevention, and is a thoroughly acceptable type of finish for many acceptable types of finish for many articles. Parco Lubrite is a manganese base phosphate coating, non-metallic and oil absorptive and because adequate oil is retained on the contacting surfaces at the critical break-in period, the break-in period is more rapid.—INCO.

5.9.4, 5.4.5

Etch Pre-Treatment Primers. E. E. HALLS. *Machinery* (London), **78,** 114-116 (1951) Jan. 18.

Discusses various types above for use on a variety of metal surfaces prior to painting, which, in addition to providing protection against corrosion, also have the effect of etching the metal surface so that adhesion of both primer and paint is considerably improved. Qualitative performance of various metals and alloys pretreated in different ways before application of enamel-type paints is tabulated.—BLR.

5.9.4

Anti-Rust and Anti-Staining Treatment of Tinplate (The "Protecta-Tin" Process). Tin Research Institute. Brochure, March, 1950, 4 pp.

This is a revised edition of the earlier publication (noted in *B.N.F. Bulletin,* Nov., 1947, p. 327) describing technique of this alkaline dip for protecting tinplate.—BNF.

5.9.4, 5.4.5

Zinc-Chromate-Pigmented Etch Primers for Metal Finishing.—I.-II. E. E. HALLS. *Brit. Ind. Finishing,* **3,** No. 28, 251-252+ (1950); No. 29, 300-302+ (1950).

I.—The importance of the adhesion of an organic finish to metal surfaces is stressed. Although chemical pretreatment of the metal ensures improved adhesion, when only one side of a component has to be painted and electrical contact is to be made on the other, treatments for steel, zinc, cadmium and aluminum, such as phosphating or anodizing cause loss of electrical contact conductance. Further, it is claimed that no satisfactory pretreatments are available for nickel and tin plating.

II.—The results of three humidity tests (of varying severity) on brass, mild steel, zinc and cadmium electrodeposits, and aluminum given various pretreatments, including a zinc-chromate-pigmented etch primer and finished with either one coat of a stoving enamel or two coats of a cellulose finish, are presented and discussed in detail. The metal etch primer showed good adhesion to all the metals tested and was retained under test conditions of high humidity and temperature.—MA.

5.9.4

Rust Proofing Improved by Polymerized Phosphate Coat. DON VANCE. *Western Metals,* **8,** 25-26 (1950) Nov.

Describes advantages of "Polykote" process developed by Kelite Products, Los Angeles. A catalyst is used to produce polymerization of the phosphate crystals, resulting in continuous rather than discontinuous protection.—BLR.

5.9.4, 3.2.3, 6.4.2

Surface Treatment and Finishing of Light Metals. Part 5. (Series continued.) S. WERNICK AND R. PINNER. *Sheet Metal Inds.,* **28,** 79-87 (1951) Jan.

Covers following aspects of the anodizing process for aluminum: theory, types of anodizing processes, application of anodizing, protective applications, decorative applications, adhesion of organic finishes, composition of the coating, dielectric or barrier layer, porosity, mechanism of film growth and secondary reactions. 33 references.—BLR.

5.10 Other

5.10, 8.4.3

Insulation Collar Prevents Corrosion. *Petroleum Refiner,* **29,** No. 11, 159-160 (1950) Nov.

Corrosion due to heavy rains and salt-laden air in the insulation of refinery and gasoline plant process vessels was prevented by eliminating the insulation around the nozzle where the corrosion occurred. A new corrosion area was discovered on the lower portion of the nozzle just under the insulation. To prevent this an insulation collar is welded to the vessel wall around the nozzle and the insulation sealed to the ring. If the seal leaks, the corrosion will not damage the vessel wall or the nozzle, but will cause corrosion of the insulation collar, which can be more easily replaced than a nozzle.—INCO.

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.2, 1.5

Cast Iron and High-Silicon Acid-Resisting Iron. R. V. RILEY, J. R. PARK AND K. SOUTHWICK. Paper before Soc. Chem. Ind., Birmingham, Apr. 18-20, 1950. Materials of Construction in the Chemical Industry, 1950, 113-123+.

Review of the types of iron now available to the chemical engineer which are considered under the headings gray cast iron, white iron, malleable iron, low alloy gray iron, martensitic irons, high chromium iron, acicular iron, nodular cast iron, heat-resisting irons, corrosion-resisting irons and high-silicon acid-resisting iron. Tables, graphs, microstuctrures and photographs of applications are given. One of the tables gives data on the resistance of silicon iron to acids, salts, mixtures of acids and salts, alkalies, and various other chemicals.—INCO.

6.2.2, 5.3.4

Metallic and Nonmetallic Coatings for Gray Iron. CHARLES O. BURGESS. *Foundry,* **78,** 76-79 (1950) Dec.

First of three articles discussing coatings successfully applied to gray-iron castings on a commercial scale to meet appearance, corrosion, wear, or other requirements. Covers sprayed-metal and hot-dipped coatings.—BLR.

6.2.2, 5.3.4

Metallic Surface Coatings for Gray Iron. C. O. BURGESS. *Product Eng.,* **21,** No. 12, 108-113 (1950) Dec.

Coatings are dealt with under the headings: Sprayed metal, hot-dipping, hard facing, cementation, electrodeposition. Coating metals mentioned include stainless steel, nickel, molybdenum, tin, zinc, lead, lead-tin, aluminum, chromium, cadmium, copper, etc. Brief details of process are given together with advantages, further treatments, etc. A previous paper by this author, (*ibid,* **21,** No. 10, 103-110 (1950) Oct.) dealt with non-metallic coatings.—BNF.

6.2.2, 5.3.4

Metallic and Nonmetallic Coatings for Gray Iron. CHARLES O. BURGESS. *Foundry,* **79,** 96-99, 225-236 (1951) Jan.

In 2nd of 3 articles, application of hard facings, diffusion coatings, and electrodeposition of various metals to gray-iron castings are discussed.

6.2.2

Rust Prevention on Ferrous Materials: Cast Iron. W. WESTWOOD. British Cast Iron Research Assoc. *Journal of Research and Development,* **3,** 545-550+ (1950) Oct.

Discusses the above in connection with corrosion by the atmosphere, "industrial" waters and soils. Presents corrosion-test results of austenitic cast iron, phosphor bronze and ordinary cast iron in a variety of chemical solutions (mostly aqueous, but a few nonaqueous). Discusses cathodic protection of pipelines.—BLR.

6.2.3

Structural Cast Iron Containing Spherical Graphite (Gusseisen mit Kugelgraphit als Konstruktionswerkstoff). A. WITTMOSER. *Z. Ver. Deut. Ing.,* **93,** No. 3, 49-57 (1951) Jan. 21.

Normal cast iron contains graphite in lamellary form. Introduction of certain elements into the casting process, alkaline earth or cerium, transforms the graphite particles into spherical shape, whereby most characteristics of the material change so decisively that the product becomes a new type of cast iron. Cast iron, treated with magnesium, shows new mechanical characteristics which are, to a large extent, equal to better grades of steel. Specifically, this is true with reference to tensile strength, the appearance of a measurable yield point, and evidence of measureable expansion and contraction. Values for impact bending resistance are superior to those of acicular cast iron. The fatigue strength may be called superior although conclusive tests are not yet available (1951). The following characteristics are also favorable: suitability for shaping by cutting, wear and tear ratio, suitability for heat treatment, thermal deformation, and corrosion resistance. Welding requires a special process and has to be further developed. The attainable damping effect is inferior to that in gray cast iron which also excels by the ease in

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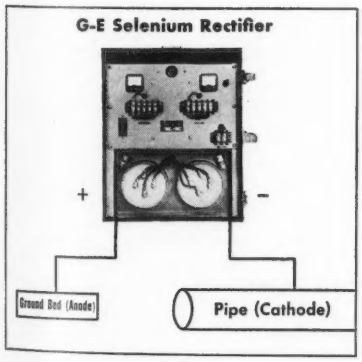

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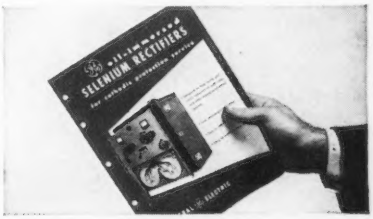

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casting, and the relatively low production cost.—TDD.

6.2.4, 6.3.6

Alloys of Copper and Iron. CYRIL STANLEY SMITH AND EARL W. PALMER. *J. Metals,* **188,** 1486-1499 (1950) Dec.

Studies were made of the mechanical and other properties of alloys over the entire composition range from pure copper to pure iron. Although the 2-phase alloys have poor corrosion resistance unless protected, the composition in the vicinity of 65 percent copper possesses an excellent combination of strength and electrical conductivity in the form of cold-drawn wire. The alloys near 5-10 percent copper have the highest strengths and are the most susceptible to improvement by age-hardening. Includes numerous graphs, tables, macrographs and micrographs. 16 references.—BLR.

6.2.4

Flakes in Pieces of Steel. (In French.) ALBERT PORTEVIN AND ETIENNE PRETET. *Rev. Met.,* **47,** 889-893 (1950) Dec. *Compt. Rend.,* **231,** 1188-1190 (1950) Nov. 27. (From document removed from sealed envelope dated June 3, 1935.)

Discusses factors responsible for the above, including influence of structure, corrosion, and rate of cooling before forging. In the discussion, Pierre Chevenard points out the value of the ideas presented, although the role of hydrogen had not yet been recognized in 1935.—BLR.

6.2.4, 6.2.5, 3.5.9

Subzero Properties of Metals Surveyed, Part I. E. J. RIPLING. Case Inst. of Tech. *Iron Age,* **166,** No. 16, 76-80 (1950) Oct. 5.

Steels to be used at low temperatures should be thoroughly deoxidized and fine-grained. Distribution of carbides should be spheroidal rather than lamellar. Tempered martensitic steels behave favorably at subzero temperatures than do pearlitic steels.—BLR.

6.2.5,-6.3.10, 3.5.9

Heat Resistant Castings—Their Selection and Application. H. R. CLAUSER. Materials & Methods, Manual No. 63. *Materials & Methods,* **32,** No. 4, 79-90 (1950) Oct.

General composition, high temperature, strength properties, corrosion resistance, special service properties and processing characteristics of the heat resistant alloys are all covered in detail. The general types of application for which each grade alloy, namely iron-chromium, iron-chromium-nickel and nickel-chromium is best suited are given. —INCO.

6.2.5

Substitute Grades Suggested for Scarce Stainless Steels. K. ROSE. *Materials and Methods,* **33,** No. 3, 87-88 (1951) Mar.

With the national emergency regulations beginning to take effect, materials engineers find that an important part of their work is the choosing of acceptable substitutes for materials no longer available or in short supply. Stainless steel, being a highly alloyed steel, is one of the groups of materials to feel the first restrictive orders. This article offers a thorough discussion of acceptable alternates available for conventional welding grades and nickel-bearing types. —TDD.

6.2.5, 3.7.2

Aluminum Decreases Corrosion Resistance of Austenitic Stainless. R. S. STEWART AND S. F. URBAN. National Lead Co. *Iron Age,* **166,** No. 7, 91-95 (1950) August 17.

It has been found that the presence of sigma phase, rather than chromium carbide precipitation is responsible for the low corrosion resistance of titanium stabilized austenitic stainless steels in boiling 65 percent nitric acid when tested after sensitizing treatment. The transformation of a portion of the delta ferrite into sigma in 321 steels apparently is due to the presence of titanium and aluminum. The presence of aluminum is usually neglected in terms of corrosion resistance and because of excess amounts added, some remains alloyed with the steel. Tests have shown that corrosion rates of titanium stainless steel increase with an increase in aluminum content. The high aluminum content increases the amount of sigma phase transformed from the ferrite present as well as the grain boundary sigma when the steel is reheated for two hours at 1250°C. Chromium-nickel ratio produces a mild influence on the corrision resistance of sensitized steel. Steel analysis table, illustrations and graph on the effect of aluminum content on corrosion are given.—INCO.

6.2.5, 3.2.2

Embrittlement of Stainless Steel by Steam in Heat Treating Atmospheres. C. A. ZAPFFE AND R. L. PHEBUS. Paper before ASM, 32nd Ann. Conv., Chicago, Oct. 23-27, 1950. Am. Soc. Metals, Preprint No. 25, 11 pp. (1950).

The special bar-bend test described in a previous paper was applied to 6 Class I (hardenable) stainless steels which were hardened over a range of temperatures from various atmospheres of dry helium, normal air and steam. Bend tests demonstrated a powerful and heretofore unrecognized effect of steam in embrittling the steel through the hydrogenizing effect of the metal-steam reaction. Steels which sustain a full bend of 180° when hardened from a dry atmosphere fail at angles as low as 20° when steam is admitted to the furnace atmosphere during heat treating; and steels which fracture at a given angle when quenched from normal air can be markedly improved by drying the furnace atmosphere. These results confirm the theory of the "H_2 potential" of steam-metal reactions previously advanced and explain numerous problems of cracking and poor ductility on the basis of the common presence of steam in furnace atmospheres as humidity and/or a reaction product of fuel-combustion. Attention is called to the practical aspects of the discovery as well as the theoretical. Illustrations.—INCO.

6.2.5, 6.3.10, 3.5.9

I. Rolled Alloys Hold Important Place in Field of Fabricated Heat Resistant Equipment. II.—High Alloy Weldments for Heat- and Corrosion-Resistant Applications. P. GOETCHEUS. *Ind. Heating,* **17,** Nos. 10, 11; 1762+ and 1928+ (1950) Oct., Nov.

Part I deals with high temperature alloys in two groups, for use below 870°C., and between 870° and 1130°C., respectively. Typical equipment is illustrated. Materials mentioned include Misco Metal (iron-35 nickel-15 chromium-1.25 silicon), Brand "A" (80 nickel-14 chromium), 25 chromium-20 nickel and other alloy steels. Part II discusses welding of cast high-alloy steels.—RPI.

6.2.5, 8.3.5

Stainless Steel Castings, Valves and Fittings Beat Corrosion in Paper Industry. N. S. MOTT. *Paper Trade J.,* **132,** 31-32, 34, 36 (1951) Jan. 26.

Typical physical and mechanical properties of cast corrosion-resistant alloys for the above; also, alloy recommendations for corrosion resistance to chemicals commonly used in the paper industry, are tabulated and discussed. Includes Ni and high-Ni alloys. 12 references.—BLR.

6.2.5, 6.3.10

Corrosion-Resistance of Stainless, Monel, and Nickel Castings. *Materials and Methods,* **29,** No. 5, 79, 81 (1949).

Data sheet.—MA.

6.2.5, 3.7.2, 3.7.3

Corrosion. M. G. FONTANA. *Ind. & Eng. Chem.,* **43,** No. 1, 69A-70A (1951) Jan.

Discussion of properly treated titanium-stabilized 18-8 sulfur stainless steels which is equivalent to columbium-stabilized material for most practical purposes includes the effect of aluminum and effects of heat treatment.—INCO.

6.2.5

How to Choose a Stainless Steel. (In French.) L. GUITTON. *Metaux & Corrosion,* **25,** No. 296, 91-99 (1950) Apr.; No. 298, 164-169 (1950) June.

A general survey of the gradations of steel, including 5-30 chromium steels, and 13-26 chromium, 12-80 nickel steels with additions of molybdenum, tungsten, copper, titanium and cobalt is given. Charts on the loss of weight of 6 steels containing from 12-26 chromium, 0-20 nickel and 2.0 molybdenum by boiling in sulfuric acid and 65 percent nitric acid are given. The effect of hydrochloric acid, hydrofluoric acid, organic acids, alkaline solutions, salt solutions, water, organic compounds and corrosive gases at high temperatures on these steels is discussed briefly. Wide application to stainless steel is found in the bleaching and dyeing industry. The author discusses the use of steel in the transportation and aviation industry, medicine, drugs and surgery, decoration and in the heating and petroleum industries. 18-10-molybdenum is used in the dyeing industry, cold rolled 18-8 for transportation equipment and 18-10 stabilized and 18-10 in the aviation industry and for surgical instruments. Resistance to corrosion is an essential factor in the choice of a steel. Choice of steel for use in cold and hot operations is outlined. Charts and photographs are given.—INCO.

6.2.5, 2.3.2, 3.7.1

Present Knowledge of Low-Carbon 18-8. H. W. GILLETT. Am. Soc. Testing Materials. Symposium on Evaluation Tests for Stainless Steels. Special Tech. Publ. No. 93, 41-54 (1950).

Reviews data from the literature on austenite stability, carbide precipitation, weldability, and corrosion resistance. Considers effect of grain size, rolling reduction, and carbon, nitrogen, chromium, nickel, copper, manganese, silicon, oxygen, molybdenum, and boron content. Discusses competence of conventional methods for evaluating sensitization and corrosion-resistance.—BLR

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6.2.5, 3.5.9

Pipe and Tubes for Elevated Temperature Service. National Tube Co., Pittsburgh. Bulletin 26, 1950, 64 pages.

Presents data on the properties of steels employed for elevated temperatures and high pressures. Covers 26 different analyses representing a wide variety of chemical compositions.

6.2.5, 3.5.8

Increasing Fatigue Strength of Stainless Steels. *Engrs. Digest,* **11,** 374-375 (1950) Nov.

A special nitriding process has been developed for the surface-hardening of both the austenitic and the ferritic stainless steels. These steels cannot be successfully nitrided by the conventional nitriding process because of the chemically inert film of chromium on the surface of the material. It is necessary to reduce this film by means of nascent hydrogen before the surface of the material will combine with nitrogen. There are many applications of stainless steels where the component in question is subjected to repeated full or partial stress reversals. Unfortunately, neither the austenitic nor the straight chromium stainless materials have particularly high fatigue strength, especially in the notched conditions. Nitriding the stainless steel is the most satisfactory means of increasing fatigue strength without materially sacrificing the other desirable properties of the base material. This increase in fatigue strength is attributed to the compressively stressed case on the surface of the piece. Generally speaking, surface hardening may increase the fatigue strength of unnotched 12 percent chromium material by 15 percent. A corresponding increase in fatigue strength of 30 percent may be obtained for a material of the 18 percent chromium-18 percent nickel type. The fatigue strength of notched material of the 12 percent chromium type may be increased by 750 percent by surface-hardening.—TIME.

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.1, 1.3

Non-Ferrous Metals (Progress in 1949). (1) D. W. WAKEMAN; (2) S. W. SMITH. Reports on the Progress of Applied Chemistry. *Soc. Chem. Ind.,* **34,** 121-138, 138-151 (1949).

D. W. Wakeman deals with physical metallurgy (pp. 121-138) covering physical and mechanical properties; properties of alloys; wrought alloys; melting and casting; corrosion and protection; 192 references.

S. W. Smith (pp. 138-151), deals with extraction and refining excluding electrometallurgy, covering copper, lead, zinc and columbium, tin, nickel, cobalt, antimony, the precious metals, aluminum, magnesium, less common and rarer metals; 93 references.—BNF.

6.3.4

Highly Corrosion Resistant Spring Material Finds Varied Use. K. ROSE. *Materials & Methods,* **32,** No. 3, 54-55 (1950) Sept.

Because of its exceptional combination of properties, Elgiloy, a 40 cobalt-20 chromium-15 nickel alloy, has found many important applications outside of its original use as a watch spring material. It is used in pen nibs, as ball bearings, electrical switch springs, threat guides, dental equipment, watch bands, drawing instruments, etc.—INCO.

6.3.5, 3.7.2

Conservation of Columbium: A Summary of British and American Experience With Stabilized Stainless Steels. *Metal Progress,* **58,** 691-708 (1950) Nov.

In an article, "Conservation of Columbium," *Metal Progress,* **58,** (1950) July, John F. Tyrrell urged the rather general substitution of titanium-stabilized steel (Type 321) for the columbium (niobium)-stabilized grade (Type 347). Presents reactions of 56 British and American metallurgists from the industries concerned. Besides comment on Mr. Tyrrell's main thesis, the discussion includes other closely related matters not dealt with in the original article—for instance, the use of stabilized steel in the chemical industries. Includes information on corrosion resistance, service failures, weldability, melting and pouring. Macrographs and micrographs.—BLR.

6.3.6, 4.3.6, 3.8.4

Rate of Solution of Copper in Different Salt Solutions and Mechanism of Corrosion of Copper. (In German.) W. KATZ. *Werkstoffe u. Korrosion,* **1,** 393-399 (1950) Oct.

Long-term experiments were made to determine rates of solution of copper in ammonium chloride, sodium chloride, potassium nitrate, sodium sulfate, sodium phosphate and sodium acetate solutions of varying concentration. It was found that copper may dissolve at accelerated, constant, or retarted rates, depending on solvent and time. Mechanism of corrosion is discussed. Differential behavior of copper in different solutions was not explained satisfactorily. Author concludes that corrosion of copper is cathodically regulated. Includes graphs and tables.

6.3.6

Corrosion Resistance of a Copper Alloy Containing Chromium. (In Japanese.) TETSUTARO MITSUHASHI AND MANABU UENO. *J. Mechanical Laboratory,* **4,** 50-53 (1950) Mar.

Data on the above are charted for alloys containing 65-90 percent copper, 5-20 percent nickel and 5-25 percent chromium.—BLR.

6.3.6

The Corrosion Products of an Ancient Chinese Bronze. R. J. GETTENS. Harvard University. *J. Chem. Educ.,* **28,** No. 2, 67-71 (1951) Feb.

Corrosion products found in Chinese vessel dating from 112-225 B.C. A sample from the rim showed an analysis of 73.8 copper, 20.3 tin, 4.6 lead with a trace of zinc and one from the base 72.3 copper, 21.8 tin, 4.1 lead with a trace of zinc. Microscopic examination revealed a zone in the center with small irregular areas of uncorroded metal, an intermediate partially mineralized zone and an outer completely mineralized zone. Photographs of these zones showing corrosion penetration, equations for the corrosion of the inner penetration and outer mineralized zones and 12 references are given.—INCO.

6.3.6

Uses Broaden for Cast Monel. N. S. MOTT. *Iron Age,* **167,** 63-67 (1951) Jan. 11.

Surveys corrosion resistance, physical and mechanical properties, microstructure, weldability, machinability and applications. Includes table of corrosion resistances versus a long series of common chemical and industrial products.—BLR.

6.3.6, 3.2.3

The Adherence of Oxide Scales on Copper. R. F. TYLECOTE. Appendix: **The Temperature of the Oxide Scale on Copper During Hot Rolling.** R. EBORALL. *J. Inst. Metals,* **78,** No. 4, 301-326 (1950-1951).

The scales formed on pure or tough-pitch copper and on phosphorous-deoxidized copper are known to behave very differently during fabrication, the phosphorous-bearing coppers shedding their scales more readily than the phosphorus-free coppers during hot-working. A corresponding difference is observed in laboratory tests when specimens are oxidized in air at hot-working temperature and then cooled to room temperature, the phosphorus-bearing coppers shedding their scales freely on cooling, while the scales on phosphorus-free coppers remain strongly adherent. These differences in scaling behavior are explained in terms of the mechanical properties of the scales at elevated temperatures. The oxide scales on copper, consisting largely of cuprous oxide, are remarkably ductile at elevated temperatures. For example, wire specimens consisting entirely of oxide ~20 percent before fracture under tensile stress at 700°-900° C, the ductility decreasing with decrease of temperature to ~5 percent elongation at 300° C. The scales on coppers containing phosphorus, on the other hand, have very limited ductility, never exceeding ~5 percent elongation over the whole temperature range and they are therefore unable to accommodate the plastic strains imposed on them by hot-working operations or by the differential contraction of metal and scale when the oxidized copper cools to room temperature. The hot shortness of these scales is due to inter-granular films of a molten phase, probably a cuprous phosphate. In the appendix an estimate is made of the temperature reached by the oxide scales when a slab preheated to 900° C is passed through the rolls. It is shown that the scale rapidly cools to a temperature at which the ductility of the scale on phosphorus-free copper is fairly strongly dependent on the temperature, and it may be inferred that moderate reductions in initial slab temperature would markedly favor exfoliation of the scale.—MA.

6.3.6, 2.3.3, 3.5.9

The Oxidation of Copper at 350° to 900° C. in Air. R. F. TYLECOTE. *J. Inst. Metals,* **78,** No. 4, 327-350 (1950-1951).

As part of a study of the adherence of oxide scales on copper and on phosphorus-deoxidized copper, the oxidation rates of these materials in air were measured in the temperature range 350°-900° C, by a continuous-weighing method. At 615° C and higher the coppers oxidize according to the parabolic law, and the rate constants are similar for the two types. At lower temperature the initial stages of oxidation depart significantly from the parabolic mode and the oxidation probably follows a logarithmic law, the rates again being similar for the two types of copper. However, as the scale

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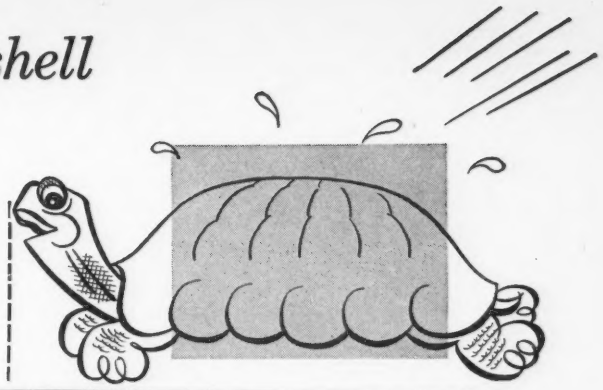

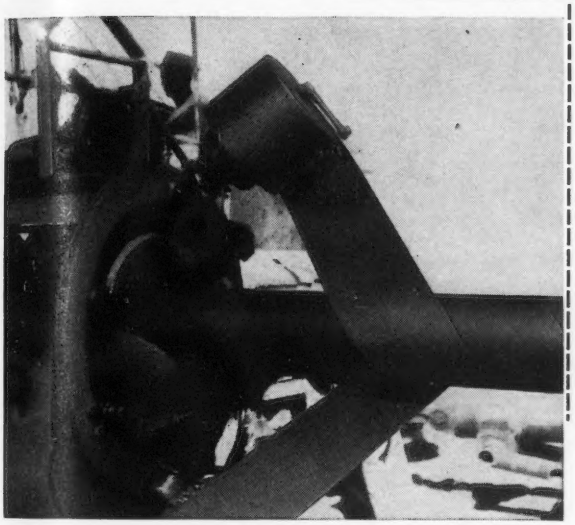

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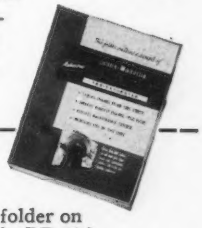

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thickens, the oxidation conforms more nearly to the parabolic law. At 450°-500° C there is a change of slope in the plot of the parabolic rate constant against the reciprocal of the absolute temperature, and at this temperature there is a similar change of slope in the analogous plot of the electrical conductivity of the oxide film. The second change is thought to account for the first and, if this is correct, no change in the mechanism of parabolic oxidation need be postulated. The results of the work have no direct bearing on the adherence of the scales on the two types of copper except in so far as the adherence may depend in part on the thickness of the scale. 18 references.—MA.

6.3.10

Nickel-Aluminum Alloy Combines Strength and Corrosion Resistance. P. O'KEEFE; *Materials & Methods,* **33,** No. 4, 73-77 (1951) Apr.

Duranickel, a relatively new corrosion resistant nickel-aluminum alloy, is a wrought, slightly magnetic metal with the strength of heat-treated alloy steel which is expected to find wide applications where corrosion resistance and high hardness and great strength at room and high temperatures are required. This article offers a thorough study of the new alloy covering such topics as: mechanical and physical properties, spring and working characteristics, thermal treatment, mill products and applications. Accompanying pictures, graphs, and tables furnish detailed information.—TDD.

6.3.10, 7.1

Heat and Corrosion Resistant Alloys. *Metal Treatment,* **17,** No. 63, 127-128 (1950) Autumn.

Nimonic 90 withstands a stress of 19 tons per sq. in. and Nimonic 80A a stress of 17 tons per sq. in. at 750° C. At 815° and 870° C, Nimonic 90 has shown high load-carrying capacity for long periods. The alloy has found successful use in the latest types of turbo-jet engines. The forging of this alloy can be satisfactorily performed in the range 1050-1150° C, but it rapidly increases in stiffness as the temperature falls below 1000° C and frequent reheatings are necessary. The heat-treatment of Nimonic 90 consists of a solution treatment of 8 hours at 1080° C, followed by air-cooling and reheating at 700° C for 16 hours and air-cooling. The analysis of this alloy has not yet been released by the Mond Nickel Co. Ltd.—INCO.

6.3.11, 3.7.2, 4.3.5

Silver Alloys With Increased Resistance to Chlorine. (In German.) I. SCHATZ. *Werkstoffe U. Korrosion,* **1,** 248-249 (1950) June-July.

Briefly tells how multivalent metals which form a solid solution with silver (especially cadmium, zinc and lead) greatly inhibit the progressive formation of silver chloride at higher temperatures. Includes graphed data and photomicrographs.—BLR.

6.3.15, 4.3.2

Corrosion Resistance of Titanium Metal in a Number of Chemical Reagents. REMINGTON ARMS CO., INC. *Materials & Methods,* **32,** No. 1, 75 (1950) July.

Gives approximate ratings in a number of acids and other corrosive liquids. —BNF.

6.3.15, 4.6.11

The Titanium Program at the U. S. Naval Experiment Station. W. L. WILLIAMS. *J. Am. Soc. Naval Eng.,* **62,** 855-869 (1950) Nov.

Included are data on the marine corrosion properties of titanium which indicate its outstanding corrosion resistance.

6.3.15

Corrosion-Resistance of Titanium Metal in a Number of Chemical Reagents. *Materials and Methods,* **32,** No. 1, 75 (1950).

Data sheet.—MA.

6.3.15, 6.3.20, 3.2.2, 3.7.2

Fabrication of Titanium and Zirconium. A. M. BOUNDS AND H. W. COPPER. Superior Tube Co. *Metal Progress,* **58,** No. 2, 185-188 (1950) Aug.

Metal-working operations (bending, drawing, forming, and welding) on the two metals titanium and zirconium are discussed. It is expected that further experience with these metals will undoubtedly bring about an evolution of tool angles and grinding techniques, since titanium and zirconium cannot be machined effectively with the same tool designs as the common metals. Titanium and zirconium are different from the common metals in that all of the reactive gases are absorbed, which causes embrittlement. The purest and most ductile titanium and zirconium is obtained by the iodide method and such metal can absorb tremendous amounts of cold work without fracture, provided that the work is introduced in steps rather than all at once. A few hundredths of a few tenths of a percent of nitrogren or oxygen alters the properties of both metals about as drastically as steel is altered by carbon up to the eutectoid composition. This means that if these metals contain more than about 0.03 percent carbon, oxygen, or nitrogen, they must be considered as alloys. Since the two metals have a hexagonal crystal structure, they gall and seize readily upon working. Data are given on how to control this tending.—TDD.

6.3.19, 4.1

"White Rust" Formation on Zinc. P. T. GILBERT AND S. E. HADDEN. *J. Inst. Metals,* **78,** No. 1, 47-70 (1950-51).

The conditions under which zinc corrodes in moist atmospheres with the formation of a voluminous white corrosion product known as "white rust" were investigated. In unpolluted air of 100 percent relative humidity zinc was only tarnished, but white rust was rapidly produced when specimens were wetted with distilled water and kept in a humid atmosphere. The corrosion product usually consisted of basic zinc carbonate, but this was sometimes mixed with zinc oxide, and in the absence of carbon dioxide zinc oxide only was detected. The rate of corrosion was not altered by removing carbon dioxide from the atmosphere, and it is concluded that the primary reaction is the formation of zinc hydroxide precipitated at the meeting place of zinc ions and hydroxyl ions formed by electrochemical action. The rate of corrosion increased considerably when polluting substances such as sulfur dioxide, hydrochloric acid, or organic acids were present in the atmosphere or when galvanizing-flux residues remained on the zinc surface. The rate of attack decreased in the presence of ammonia or high concentrations of carbon dioxide. Precautions necessary to avoid white rusting in storage or transit are discussed. Simple immersion treatments in dilute chromate solutions are shown to give considerable protection, as did quenching in similar solutions after galvanizing.—MA.

6.3.20

Zirconium — Once a Rare Metal, It Is Now Ready for Commercial Use. A. H. ROBERSON AND W. W. STEPHENS. Bureau of Mines. *Modern Metals,* **6,** No. 8, 36-38 (1950) Sept. *Materials & Methods,* **32,** No. 4, 63-64 (1950) Oct.

The development of zirconium and its commercial uses are discussed. A description is given of a new process which permits the large-scale production of malleable zirconium at a considerably reduced cost. Zirconium possesses properties which make it useful in constructing reactors for harnessing atomic energy, for chemical plant equipment requiring superior corrosion resistance, and for various surgical applications. The most significant property of zirconium is its resistance to corrosion and its most spectacular application is in surgery where it is especially valuable in bone repairs.—TDD.

6.3.19

Materials Engineering File Facts. 1) Cast Zinc Alloys. 2) Wrought Zinc Alloys. *Materials & Methods,* **32,** No. 4, 91, 93 (1950) Oct.

Gives composition; physical, mechanical and fabricating properties; corrosion resistance; uses; for casting alloys XXIII and XXV (zinc-aluminum-magnesium and zinc-aluminum-copper-magnesium), slush-casting alloys, "unbreakable metal", and 5 rolled materials (commercial zinc, deep-drawing zinc, zinc-copper and zinc-copper-magnesium).—BNF.

6.3.20

Zirconium Offers Interesting Properties and Possibilities. *Materials & Methods,* **32,** No. 4, 63-64 (1950) Oct.

Zirconium has many potential applications in addition to its extensive use in electronics. Because of excellent corrosion resistance and nontoxicity it could be employed in surgical parts and appliances. Zirconium makes satisfactory glass-to-metal seals and therefore could be utilized in glass-lined tanks. It could also be used for scientific weights. As an alloying element, zirconium gives magnesium alloy good extruding characteristics and end-service properties. Zirconium alloys containing aluminum to increase the hot strength of the alloy may find possible use in high temperature aircraft.

Zirconium is not corroded by ordinary industrial atmospheres, or by common alkalies or acids, except hydrofluoric acid. When annealed, it has an ultimate strength of 34,000-45,000 psi and a yield strength of 11,000-20,000 psi. The strength declines rapidly at elevated temperatures. Zirconium can be cold-drawn and rolled but because of gas sensitivity it must be vacuum-annealed. —PDA.

6.3.20

Zirconium. G. L. MILLER. *Ind. Chemist,* **26,** No. 309, 435-441 (1950) Oct.

After referring to the iodide process, preparation of zirconium by the Kroll process is described with illustrations showing the Rainham plant of Murex, Ltd. Mechanical and physical prop-

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erties, corrosion resistance, fabrication methods and applications of zirconium are given. 6 Figures.—BNF.

6.4 Non-Ferrous Metals and Alloys—Light

6.4.2

Magnetic Separator Housed in Aluminium. *Modern Metals,* **6,** No. 12, 32 (1951) Jan.

Aluminum was selected for use in the ATOMagnet magnetic separators made by the Eriez Manufacturing Company of Erie, Pa. because it is non-magnetic in addition to its light weight, strength, corrosion resistance and forming properties. The rectangular magnetic area is enclosed with strips of 24S-T4 alloy which insulate the magnets to prevent power loss to surrounding areas. Aluminum sheet is used for the continuous offset hinge on the separator so that it will not attract iron particles. The magnets are of cast Alnico alloy and are enclosed in a cover of 52S-H34 aluminum sheet. The substitution of aluminum alloy 3S rivets for bolts and nuts has improved appearance, increased rigidity and decreased overall weight. The end plates of the magnetic separator are cast in alloy 108 and various other parts are made of alloys 61S-T6 and 24S-T3. —ALL.

6.4.2, 4.6.11

Durability of Aluminum and its Alloys: Marine Exposure. *Light Metals,* **13,** No. 153, 556-563 (1950) Nov. Dec. **14,** No. 154, 36-43 (1951) Jan.

Some useful corrosion precautions mentioned. Sea water exposure tests showing advantages and limitations are given in 2nd article.

6.4.2

Corrosion Resistance of Anodically Polished and "Eloxidized" Aluminum Mirrors. (In German). W. KERTH. *Metalloberflache,* **4,** sec. A, 190 (1950) Dec.

Experiments made under corrosive conditions showed that aluminum mirrors coated with a thin film of aluminum oxide are highly resistant to corrosion.—BLR.

6.4.2, 5.9.4

Surface Protection of Aluminum. G. P. BOLOGNESI AND G. MANTOVANI. *Pitturee Vernici,* **6,** No. 10, 443+ (1950).

Comparative examination has been made of various surface pretreatments for aluminum. The treatments applied were based on anodic oxidation, alkaline chromate, gelatin/dichromate, phosphate, anodic oxidation and phosphate, and arsenate. The treated specimens were tested before and after painting for resistance to corrosion by an electrochemical and saltspray method and after painting for scratch and impact resistance and adhesion (cross-cut test). The best results throughout were given by anodic oxidation, two of the alkaline chromate treatments and gelatin/dichromate treatment. Phosphatizing gave little direct protection but improved the performance of the painted specimens.—RPI.

6.4.2

Influence of Oxide Film on the Corrosion of Aluminum by Dilute Ammonia. L. RAVALD. *Chemistry and Industry,* **1950,** No. 34, 638 Aug. 26.

Dilute aqueous ammonia normally has little action on aluminum. If the initial oxide film is removed with fine emery, the rate of attack is increased but becomes very low again after a few days. The high rate of attack after abrasion can be maintained by excluding oxygen to prevent renewal of the oxide film.—BNF.

6.4.2, 4.3.3, 3.4.6

The Corrosion of Aluminium. L. A. RAVALD AND J. M. BRYAN. *Chemistry and Industry,* **1950,** No. 34, 638 — Letters.

Ravald refers to recent work by Bryan, *J. Soc. Chem. Ind.,* **69,** 169 (1950), and briefly reports observations made in the course of qualitative experiments on the action of ammonium hydroxide on 99.99 percent aluminum at room temperature, in the presence and absence of air. In the case of specimens on which the oxide surface film was intact the action of normal ammonium hydroxide in the presence of air was slight, but on surfaces abraded with fine emery cloth the rate initially increased, slowing down again in the course of a few days; in a pure nitrogen atmosphere the attack was persistent and much more rapid. The action occurring on the abraded specimen in the absence of oxygen was interrupted by exposure to air for 2 or 3 hr., and did not recur on re-immersion in normal ammonium hydroxide under the oxygen-free conditions. Dilute aqueous solutions of the ammonium carbonates had no corrosive effect and the action of normal ammonium hydroxide on commercial high-silicon alloy was considerably less than that on pure aluminum. Bryan quotes analogous results obtained on chromium-nickel steels immersed in 1 percent citric acid solution which, in conjunction with the observations by Ravald, indicate that the repair of the surface film by dissolved oxygen can take place either in weak acid or weak alkaline solutions.—MA.

6.4.2, 1.3

A Survey and Description of Processes for the Protection of Aluminium and Aluminium Alloys Against Corrosion. W. WIEDERHOLT. Board of Trade, Tech. Inf. & Docs. Unit, FD. 788/50, Frames 1-26.—RPI.

6.4.2

Aluminum and Its Alloys in 1950. E. ELLIOTT. Aluminium Development Assoc. *Metallurgia,* **43,** No. 256, 69-72 (1951) Feb.

Science and technology, contrary to the popular view, achieve their ends, not by leaps and bounds, but by steady advance throughout the years, adding always to the externally incomplete library of knowledge. With a few notable exceptions — such as 1886 in the case of aluminum — it would be difficult to label any particular year in the history of a metal as a period of revolutionary discovery, and, although technical progress in the aluminum field has followed this rule during the past year, many interesting and important articles and papers have been published. A number of these papers on the progress made in 1950 in the field of aluminum are reviewed in this article and cover the following subjects: production, melting and casting, working, joining, constitution, properties and corrosion.—TDD.

6.4.2

Corrosion of Aluminium Compared with that of Steel: Influence of Oxide Film on the Corrosion of Chromium-Nickel Steel by Citric Acid. J. M. BRYAN. *Chemistry & Ind.,* **1950,** No. 34, 638 Aug. 26.

The corrosion of chromium-nickel steel in 1 percent citric acid is affected by abrasion and exclusion of air in a similar manner to aluminum in dilute ammonia. —BNF.

6.4.2, 8.1.2

Aluminium Corrosion: Some Points to Consider. W. C. DEVEREUX. *Nat. Builder,* **28,** No. 9, 216-217 (1949).

Devereux argues that some builders have pessimistic views on the corrosion-resistance of aluminum alloys, which are based on the failure of these alloys in some cases to meet the rigid requirements for aircraft materials. The initial corrosion, although resulting in the formation of a protective layer, is serious in aircraft where very thin sheets of material are used, but such corrosion can be discounted when considering the thicker materials used for building structures.—MA.

6.4.2, 8.1.2

Edgewater's Aluminium Sign Weathers the Storm. *Alcoa News,* **22,** No. 1, 5 (1951) Jan. 8.

The largest aluminum advertising sign in the world which stretches for some 216 feet along the roof above the tenth floor of one of the buildings at the Edgewater plant of the Aluminum Company of America stood unharmed recently during a night and day of battering by winds with a velocity up to 100 mph. The 60-foot high sign is constructed entirely of aluminum with the exception of the neon tubing. The height of the letters ALCOA is 20 feet; the letters spelling out the name of the company are 8 feet high; and the trademark shield measures 24 x 37 feet. The durability and construction of Alcoa's sign was in sharp contrast to nearby damaged structures.—ALL.

6.4.2, 7.10

Aluminium Windows. *Brit. Ind. Finishing,* **3,** No. 28, 255-257 (1950).

Examples of the durability of aluminum windows are given. Painting is not essential for protection, but affords enhanced durability. Zinc chrome or barium chromate primers are recommended, but the use of lead-based paints is not advised. Interaction between aluminum and masonry, mortar or steel is satisfactorily prevented by a bituminous paint or a zinc chrome jointing compound.—RPI.

6.4.2, 5.9.4, 7.8

The Insulation of Aluminium Wire, Ribbon, or Strip, by Anodic Oxidation. *Light Metals* (England), **13,** No. 152, 507-508 (1950) Sept.-Oct.

The first example of the commercial continuous anodizing of aluminum wire, strip or ribbon to provide electrical insulation is now in operation at the works of the Sté. La Mécanique de Précision, Asniéres. Six lines of strip or wire can be passed through the machine simultaneously at a constant but adjustable speed. Currents up to 1,000 amperes are employed in the anodizing tanks. The process consists of cleaning and degreasing, rinsing, anodizing, washing, drying, a bath of dilute synthetic resin varnish, curing and rolling on six separate drums.—ALL.

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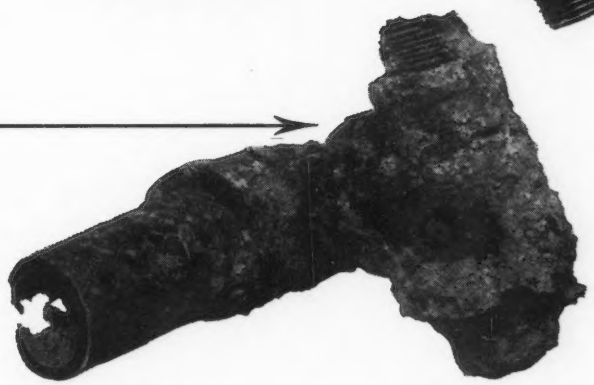

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163

6.4.2, 3.2.2

Durability (Corrosion) of Aluminium and its Alloys. *Light Metals,* **13,** No. 147, 195-203; No. 149, 344-349 (1950) April, June.

In progress. This article is the general introduction to a series. Considers durability of various aluminum alloys, types of corrosion and susceptibility of some aluminum alloys to inter-crytalline corrosion, galvanic corrosion, influence of design on corrosion. 10 references.—BNF.

6.4.2

Copper - Bearing, High - Strength Wrought Aluminum Alloys; Typical Properties. *Materials and Methods,* **32,** 83 (1950) Dec.

Table covers compositions, physical, mechanical and fabricating properties, corrosion resistance, available forms and typical uses for 11S, 14S, 17S, R317 and 24S.—BLR.

6.4.2

Properties and Use of Duralite (Termafond C3-INA). Instituto Sperimentale dei Metalli Leggeri. *Alluminio* (Italy), **19,** No. 4, 357-368 (1950).

A heat-resistant alloy (aluminum-3 copper-1.5 iron-0.7 silicon-0.6 nickel-0.15 titanium) is claimed to be an improvement over Y-alloy. Physical and mechanical properties, microstructure, heat treatment and applications are given for the cast and semi-finished state, together with notes on casting, working, jointing and surface treatments.—ALL.

6.4.2, 3.7.2

The Tensile Properties of Heat-Treated Aluminum-Copper and Aluminum-Copper-Cadmium Alloys of Commercial Purity. H. K. Hardy. *J. Inst. Metals,* **78,** Pt. 6, 657-666 (1951) Feb.

Previous work showed that additions of cadmium accelerated the artificial ageing and markedly increased the strength properties of cast and heat-treated aluminum-4 percent copper-0.15 perecnt titanium alloys of very high purity. Aluminum-copper-cadmium alloys of normal purity have now been examined in the cast or wrought condition. Alloys with more than 0.1 percent cadmium were hot short and generally failed to forge. The quantity of cadmium was not critical in the case of cast alloys, and up to 0.5 percent had no detrimental effect on the ductility of fully heat-treated test-bars at room temperature. Cadmium additions increased the strength properties of artificially aged aluminum-copper alloys to an important extent and slightly improved the resistance to corrosion by salt spray. Such alloys merit consideration for industrial use. The effect of cadmium was not influenced by the presence of iron, silicon, manganese, zinc, nickel, or 0.05 percent magnesium. Cadmium additions did not affect the ageing at 132° C of wrought aluminum-zinc-magnesium and aluminum-zinc-magnesium-copper alloys.—TDD.

6.4.2, 8.10.2

Electrolysis of Aluminum Solutions in a Magnetic Field. Charles E. Wood and C. W. Tittle. *J. Chem. Phys.,* **18,** 1683 (1950) Dec.

Formation of a molten deposit on the aluminum anode of an electrolytic cell with a platinum cathode and an electrolyte of aqueous aluminum sulfate in the presence of a magnetic field of 2000 gauss was reported by Antonoff and Rowley. These experiments were repeated with magnetic inductions up to 8160 gauss under a variety of conditions. In none of the experiments was the molten deposit formed. Corrosion was evident in all cases.—BLR.

6.4.2, 3.2.3

The Oxide Film on Aluminium. G. Tolley. *Metal Ind.* (London), **77,** No. 23, 255-258 (1950) Dec. 8.

A review of the experimental facts regarding the oxide film on aluminum shows that its protective nature has been definitely established, but there is still insufficient knowledge regarding the porosity, permeability, kinetics of formation and the properties of the film under various conditions. The oxide film normally present is amorphous, but under certain conditions crystalline modifications may appear. All the crystalline varieties of alumina except corundum can appear in the corrosion products on aluminum. It has been shown that the permeability and electrical characteristics of alumina films are considerably changed upon sealing in boiling water for 15 minutes. No all-inclusive theory can be given for the conditions governing penetration by various ions until further experimental work has been done on the coagulating, penetrating and oxidizing properties of the more common ions. Little work has been done to determine the thickness of the oxide film formed by exposure to air at room temperature. It is suggested that the method of Brunauer, Emmett and Teller for measuring surface areas should be used to accurately determine surface thickness. Conflicting experimental evidence complicates the formation of theories on high temperature oxidation. If the oxide film is penetrated localized corrosion may result or if the film is undermined or dissolved the attack may be generally distributed. Corrosion may be reduced or stopped by the repair or reinforcement of weak points in the film. 23 references.—ALL.

6.4.4

Preparation of High Purity Magnesium and a Study of the effect of Non-Metallic and Alkali Metal Impurities on the Corrosion Characteristics of Pure Magnesium. Dow Chemical Co. Third Quarterly Report; June 1, 1950—August 31, 1950. 1950. 39p (COO-15).

Plots are presented showing the effect of 1 through 8 sublimations on the amount of impurity removed from magnesium via the residues. Research on the spectrographic analytical methods has lead to increased sensitivity for alkali metals thus affording a broader evaluation of the contamination picture. The nonmetallic contaminants have also been investigated via the analysis of sublimation residues. Corrosion data on hgih-purity magnesium in various conditions are given.—TDD.

6.4.4, 8.9.1, 5.9.1

Magnesium Alloy Dissimilar Metal Corrosion. Magnesium Alloy Castings—Corrosion Protection Against Effects of Water and Leaded Fuel. Consolidated Vultee Aircraft Corp. Board of Trade, Tec. Inf. & Docs. Unit, ORR. 360/50, PB, 99964 and 100006. 61 Frames.

The protection against corrosion of AMC52S-H magnesium alloy afforded by various surface treatments (including zinc chrome primer) has been evaluated.—RPI.

6.4.4, 3.7.4, 5.3.2

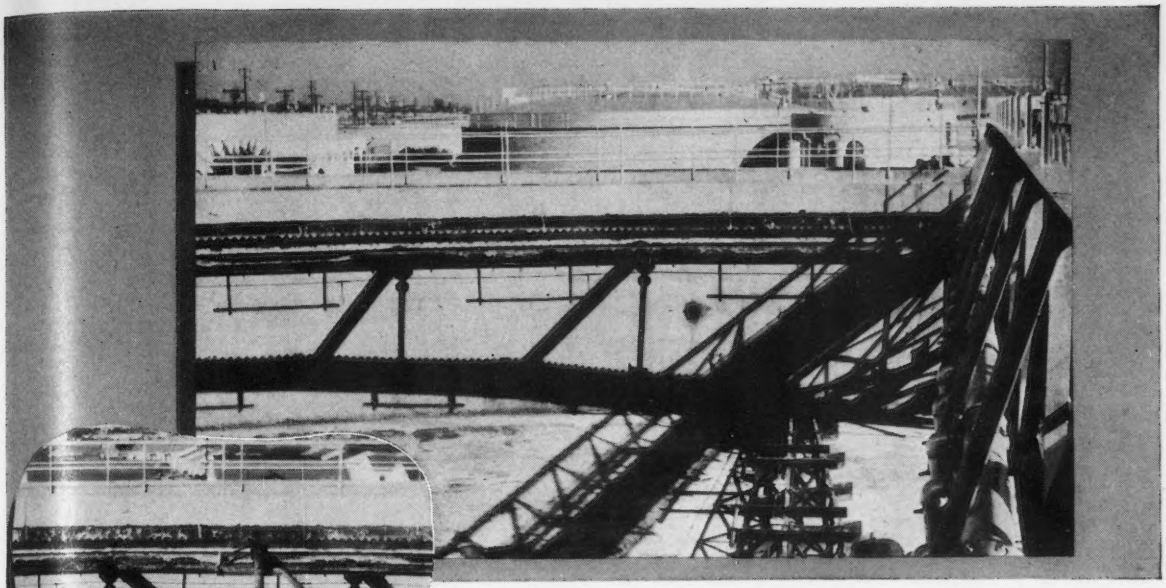
Effect of Surface Contamination on the Corrosion of Magnesium-Manganese Alloy Sheets. (In French.) L. Rakowski. *Métaux & Corrosion,* **24,** 193-210 (1940) Sept. *Metallurgia,* **42,** No. 254, 362-366 (1950) Dec.

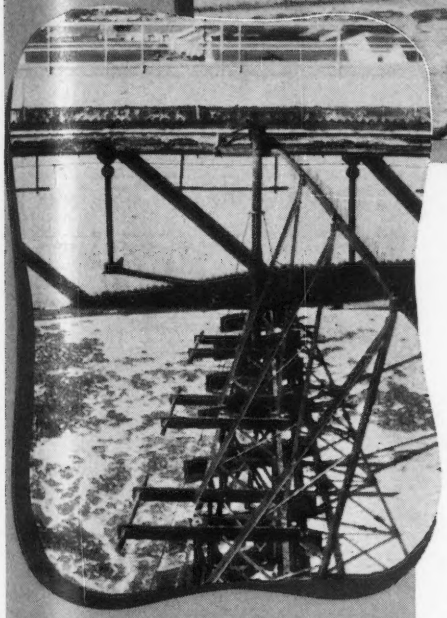
Experimental investigation of the above indicates that difficulties encountered at times during chromizing of DTD 118 alloy sheets are caused by surface contamination and heterogeneity of the alloy surface. Methods of avoiding such difficulties are indicated. Data are tabulated and charted. Includes numerous photographs showing effects of different corrosive media on specimens prepared in different ways.—BLR.

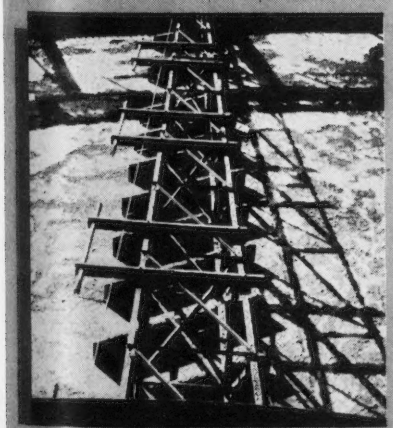
6.4.4, 8.9.1

Elektron Magnesium-Zirconium Alloy Progress. C. J. P. Ball. *Magazine of Magnesium,* **1950,** 8-11, Nov.

The properties of the magnesium-zirconium alloys developed by Magnesium Elektron Limited has been continually improved and the number and scope of their applications have increased. Elektron Z5Z, a high strength cast alloy for use at temperatures up to 300°F (147°C), has excellent fatigue characteristics, high proof stress, reasonable elongation and shows less scattering of properties throughout the casting than the magnesium-aluminum-zinc alloys. Elektron Z5Z is used for practically all new aircraft landing wheels and for structural castings and engine castings where high temperature strength is not required. Elektron ZRE1, which is used primarily for castings at high temperatures, possesses excellent creep resistance, high fatigue strength and is virtually free from microporosity and is easily cast into difficult shapes. These properties make the alloy particularly suitable for castings in jet and propeller turbine engines for parts operating up to 500°F (260°C) and for parts required to withstand very high pressures. Both Elektron Z5Z and ZRE1 are more resistant to corrosion than the commercial purity aluminum-containing alloys. The alloys are not only closely associated with the British aircraft industry, but have been licensed to foundries in Canada, U. S. A., Sweden, Holland and Switzerland. Prior to the development of magnesium-zirconium-zinc alloys, no wrought magnesium alloys were used in the aircraft industry. These alloys have high solidus temperature and very fine grain which permits the working of direct chill cast stock at high temperatures and speeds of deformation. Elektron ZW3 has extremely good formability over a wide temperature range and is the only high strength magnesium base alloy which can be worked by the drop hammer. ZW3 can be satisfactorily welded but the alloys ZW2 and ZW1 with a lower zinc content are used where the degree of constraint is especially high. These two latter alloys have mechanical properties only slightly lower than ZW3 and complex structures can be welded from sheet, tube and extruded section without weld cracking. The alloys ZW3, ZW2, and ZW1 have good resistance to corrosion and are free from stress corrosion tendencies in service. The advantages of ZW3 in hot working qualities, mechanical properties and welding have led to increased demands for the alloy. Sheet and extrusions have been used for primary aircraft components such as wings, for secondary compo-







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nents and fittings and large diameter ZW3 tubing has been successfully used as warp beams in the textile industry.—ALL.

6.4.4, 3.5.8, 2.3.7

Stress-Corrosion of Magnesium Alloys. E. C. W. PERRYMAN, *J. Inst. Metals*, **78**, Pt. 6, 621-642 (1951) Feb.

The stress-corrosion properties of magnesium-5 percent aluminum alloy in distilled water and other solutions have been investigated. Stress-corrosion tests were also carried out on other commercial magnesium-base alloys and on high-purity magnesium. The susceptibility to stress-corrosion failure of the various commercial alloys tested was consistent with their reported service behavior, the magnesium-manganese and magnesium-zinc-zirconium alloys being more resistant than the magnesium-aluminum alloys. All the alloys tested and also high-purity magnesium suffered stress-corrosion cracking in 0.5 percent potassium hydrogen fluoride solution. No detailed mechanism of stress-corrosion cracking in magnesium-base alloys is put forward, though the results show that the process is in part electrichemical. It is thought that cracking may be associated with minor impurities, e.g., iron, which are known to have a deleterious effect on the ordinary corrosion-resistance.—ALL.

6.4.4, 8.9.1, 3.5.8

Extensive Tests Conducted to Determine Magnesium's Suitability for Aircraft Use. *Steel*, **127**, No. 16, 146, 148 (1950) Oct. 16.

The U. S. National Bureau of Standards in co-operation with the Bureau of Aeronautics, Department of the Navy, has conducted an extensive investigation of the resistance of wrought magnesium alloys to corrosion under stress, both in marine atmosphere and inland atmosphere. Investigation included both sheet and extruded alloys. Specimens were exposed to weather stressed in tension at the National Bureau of Standards in Washington and in a marine atmosphere at Hampton Roads, Va. Unstressed specimens were subjected to the same corrosive conditions in order that the effect of stress in increasing corrosion damage could be evaluated.

In general, susceptibility of magnesium alloys to stress corrosion in the weather increased with aluminum content up to about 6.5 percent of aluminum. It was found that specimens stressed at the Washington weather exposure site failed in shorter periods than those exposed to the same stress in a marine atmosphere.

Of all the materials studied, the Ml-clad AZ31X-h alloy was the most resistant to stress corrosion. Specimens of this alloy were exposed in a marine atmosphere, stressed, to 90 percent of yield strength, for 500 days without failure. The Ml-h sheet and the ZK-60 extruded material, among the bare alloys, were best in regard to stress corrosion resistance. After 1175 days of exposure to weather at Washington, under a stress of 16,000 pounds per sq. in. or 55 percent of yield strength, the former sheet alloy had not failed. First failures of the ZK-60 extruded material exposed in the same locality under a stress of 20,000 pounds per sq. in. occurred only after 580 days, while specimens stressed to 18,000 pounds per sq. in. had not failed in over 1010 days. Of the remaining alloys tested, the bare AZ31X-h material proved the most resistant to stress corrosion. Specimens stressed to 16,000 pounds per sq. in., about 50 percent of yield strength, and exposed to the weather at Washington failed after an average exposure period of only 151 days. The AZ51X, AZ61X and AZ80X alloys were all susceptible to stress corrosion when exposed outdoors under stresses of 20,000 pounds per sq. in. or more. Extruded AZ80X material was more resistant to stress corrosion in the heat-treated and aged conditions than in the "as extruded" conditions.—ALL.

6.5 Metals Multiple or Combined

6.5

Metallurgical Developments in 1950. *Engineer*, **191**, No. 4957, 119-121 (1951) Jan. 26.

Review of metallurgical developments in 1950 includes copper and copper alloys, nickel and nickel alloys, other nonferrous alloys, alloy steels, heat-resisting steels and alloys, magnetic materials and cast iron. New uses were found for nickel-clad steel in the beet sugar industry, for Monel as a sheathing for steel exposed to sea water, for Inconel in the chemical and food industries and for Inconel X for sheet metal parts of jet engines and rocket motor assemblies. Other nickel alloys long prominent are those of high-temperature use, the nickel-molybdenum base alloys for resistance to attack by acid and the nickel-cobalt-iron alloys for making tight glass-to-metal seals. Two stainless steels further developed were Armco 17-4PH (17 chromium-4 nickel-4 copper) and Armco 17-7PH (17 chromium-7 nickel-1 aluminum.—INCO.

6.6 Non-Metallic Materials

6.6.5, 1.3

Corrosion Resistant Flooring Materials. *Ind. Finishing*, **3**, No. 31, 490-497 (1951).

A review of the commercial cements used.

6.6.5

Corrosion-Resistant Floors. L. H. GRIFFITHS. Paper before Soc. Chem. Ind., Birmingham, Apr. 18-20, 1950. Materials of Construction in the Chemical Industry, 1950, 9-14.

The question of floors and floor coverings is dealt with insofar as they refer to coverings and not to the actual base construction which is to carry the load. Discussion includes severe corrosion, corrosion-resistant cements and mild corrosion. To withstand severe corrosion, a brick or tile floor is generally essential. There is usually provided under the brick or tile floor, a membrane or layer of impervious and acid-proof material which provides a second line of defense. The various types, properties and uses of corrosion-resistant cements are briefly discussed. These include silicate, rubber latex, hydraulic sulfur, synthetic resin, phenolic resin and furane resin cements. —INCO.

6.6.6, 6.7.2, 7.6.9

A Survey for Ceramic for Nuclear Reactors. R. F. GELLER. *Nucleonics*, **7**, 3-17 (1950) Oct.

Tabulates and discusses physical properties of 24 ceramic materials. Possible ceramic applications in nuclear reactors and methods for preliminary evaluation are outlined. Includes carbides and metal-ceramic combinations.—BLR.

6.6.6, 6.7.2, 3.5.9

Developments in High-Temperature Metals and Ceramics. H. THURNAUER. Amer. Lava Corp. *Elec. M.*, **47**, No. 3, 82-85 (1951) Mar.

Refractory type metals, ceramics, and metal-ceramic compounds are particularly desirable in contemporary product design. Not only resistance to elevated temperatures is emphasized, but also combinations of other special characteristics such as superior mechanical strength and high insulation resistance. Technological progress carries in its wake requirements for materials which must withstand high temperatures. There are numerous cases where progress is retarded merely by the lack of suitable refractories or where efficiency has to be sacrificed due to the temperature limitations of the structural materials available; for example, the development of gas turbines, jet engines, rockets and rocket motors, nuclear reactors, and in general most chemical processes where heat and pressure reactions are involved. Even progress in the electronics field is retarded by lack of suitable materials capable of withstanding high temperatures. Therefore, during recent years a great amount of research and development work is being directed toward high temperature refractory materials. Emphasis is not only placed on refractory qualities, but rather on combinations of several properties. These may be resistant against oxidation or chemical attack, high mechanical strength at elevated temperatures, or high insulation resistance. For nuclear reactors, nuclear properties of the elements have to be considered, such as capture cross section, scattering cross section, energy loss, and slowing-down power. Last, but not least, formability and availability are determining factors. This short report is concerned only with those materials which either have found technical applications or may be considered practical at this time.—TDD.

6.6.8, 7.10

Flexible Corrosion Resistant Plastic Solves Gasket Problems. B. G. STAPLES. Pfaudler Co. *Materials & Methods*, **32**, No. 6, 48-49 (1950) Dec.

Teflon rings and tape prove good gasket and gasket-protecting materials for use in chemical processing equipment. Procedure for forming gaskets good for pressures up to 300 psi from strips of Teflon tape is described. Use of Teflon washers is given.—INCO.

6.6.8

Some Important Research Work in Reinforced Plastics. *Plastics Industry*, 9, No. 2, 27-28 (1951) Feb.

A number of unique plastics products have recently been developed. On of these items is a versatile structure that may have uses as housing for military and civilian personnel, portable shelter in both arctic and tropic climates and emergency storage facilities. The new structure is molded from Fiberglas impregnated with polyester resin. The basic unit is designed in the shape of an igloo. It is composed of 12 identical panels and, by means of separator or adapter rings which replace joining panels, any number of the units can be combined to make large structures with ells, T's,

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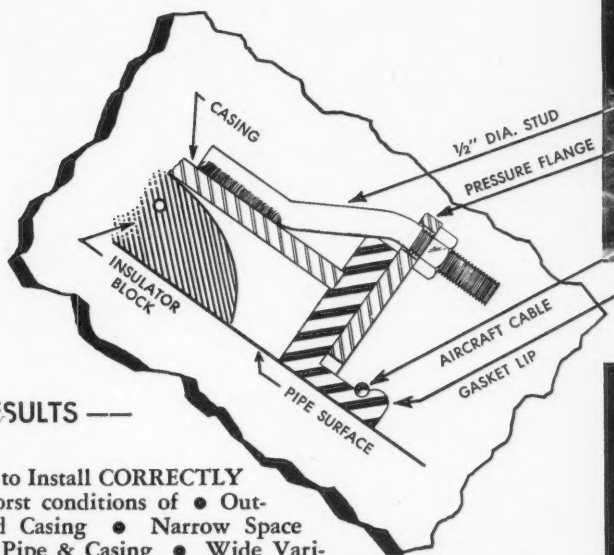
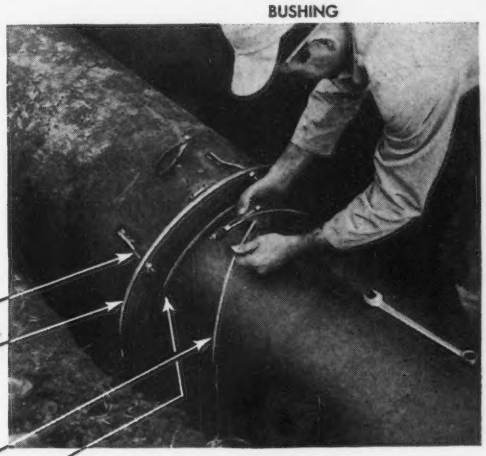
A New Design: It BUTTS Against End of Casing Instead of Fitting Inside the Casing.





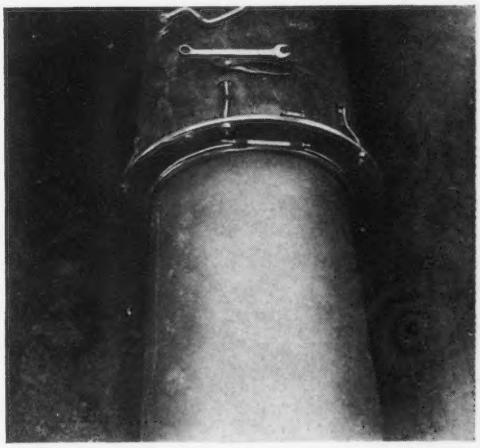
Assembling cable with rubber-covered union for clamping gasket lip to pipe.

RESULTS —

1. Easier to Install CORRECTLY under worst conditions of • Out-Of-Round Casing • Narrow Space Between Pipe & Casing • Wide Variations in Casing Wall and Coating Thickness • Mud • Casing ends beveled — by machine or hand torch.

2. WATER-TIGHT Seal with "L" gasket . . . . . .
   - BUTTED AGAINST CASING as pressure flange is tightened on ½" studs welded to casing.
   - TIGHT TO THE PIPE as aircraft cable (4,600# tensile) is tightened to gasket lip. Union is rubber covered to INSULATE galvanized cable assembly from bare casing structure.

3. Always Insulated from the pipe line when a Concentric-Support Insulator is installed just inside casing after the "drag section" is in place.



THE COMPLETED INSTALLATION
Note that galvanized cable and union are insulated from pressure flange and from pipe.

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WRITE FOR BULLETIN 249A

T. D. Williamson, Inc.
TULSA 9, OKLAHOMA

8,000 Pipe Line Casings installed in 1951 with Williamson Bushings and Insulators.

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wings, or any other desired schematic design. The entire unit, 20 ft. diameter at base, weighs about 700 lbs. Another unique product is collapsible—but air-tight—drum. Key to functioning of the drum is its "Moorex-Seal," which provides a top and bottom member at each sealing edge. A neoprene sealing element on the top member provides the shut off, and keeps both edges aligned. The laminated plastics material insures that the container is moisture and condensation proof, durable, and resistant to dents and damage. The collapsible feature saves valuable space. Quick assembly and knock down minimizes labor of handling. A reinforced wing structure using glass fiber and resin has also been developed. However, very little can be said because of security restrictons. It is self-

ribbed, with the laminated skin varying in thickness from 0.021 in. outboard to 0.25 in. inboard. This extremely thin-skin range is made possible by the use of cellular cellulose acetate material as sandwich, giving support and enabling the glass fiber skin to create tension strengths not otherwise available except with much heavier construction.—TDD.

6.7 Duplex Materials

6.7.3, 4.3.2

Welded Fabrications in Corrosion-Resistant Materials Give Engineers Great Latitude in Design of Industrial Equipment. R. J. Tierney. *Steel,* **125,** No. 23, 92-93, 130 (1949).

Tierney mentions some general economic considerations in the utilization of corrosion-resistant metals and alloys and gives particulars of a Monel-clad steel tank for use in the sulfuric acid anodizing of aluminum. The cladding is on the outside of the tank and the inside is lined with layer-welded lead.—MA.

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1

The Causes and Prevention of Corrosion in Industrial Type Steam Turbines. *Eng. and Boiler House Rev.,* **64,** 238-242 (1949) Aug.

The two distinct types of attack which damage industrial-type steam turbines are described, and methods of preventon are discussed. Electrolytic attack as a result of stray current or magnetic fields is not responsible for corrosion.

The first type of attack occurs during standing and results from salts introduced into the turbine from the steam from the boiler and from back leakages of steam into the turbine where the steam condenses. The source of salt in the boiler water is the zeolite added for softening.

The second type of attack is either an erosion or an erosion-corrosion attack and results from steam impinging at high velocity on various parts of the turbine during running.

The first effect can be minimized by using a zeolite base exchange as a softener to remove only the last trace of hardness not removed by previous soda-lime treatment and by preventing steam from leaking back into the turbine by a system of double isolating valves. The continuous or even occasional injection of graphite into the turbine also gives reasonable protection. The use of chromate inhibitor appears promising but involves too much development work.

The escond effect can be minimized by using a sufficient degree of superheat to render the system dry-saturated or practically so.—PDA.

7.1, 3.2.2

Deterioration of Diesel Cylinder Liners. F. N. Speller and F. L. LaQue. *Corrosion,* **6,** No. 7, 209-215 (1950) July. Disc., No. 10, 347-350 (1950) Oct. *Plant,* **2,** 38-41 (1950) Nov.

Describes and illustrates a peculiar form of corrosion encountered on cast-iron cylinder liners of various types of Diesel engines. Suggests possible remedies and urges cooperative research to solve the problem. Ordinary corrosion of liners and crevice corrosion are also briefly discussed.—BLR.

7.1

Test of Bonded Bi-Metallic Piston. *SAE Journal,* **58,** 80 (1950) Nov.

Based on "Bi-Metallic Pistons," by Charles E. Stevens, Jr. The problem of making a bonded bimetallic piston, or an aluminum piston having a ferrous member cast and bonded in place to receive one or more ring grooves, has been one of developing a technique which would permit the casting to cool to room temperature without bond failure. A solution to this problem was reached by using high-nickel cast irons having a high coefficient of expansion. Comparison of an all-aluminum piston shows that ring-groove wear is greatly reduced by use of a ferrous insert.—BLR.

8. INDUSTRIES

8.4 Group 4

8.4.3

Corrosion in Refineries. *Ind. Petrole,* **18,** 438-439 (1950) Sept.

Specific places in the refinery where humid, dry and stress corrosion occurs are described, with general notes on the type of metal used to counteract the corrosion.

8.4.3, 3.5.8

What Do You Know About Drill-Collar Failures? S. C. Moore. Drill Collar Service Company. Paper before Am. Assoc. Oilwell Drilling Contractors, Tulsa, Oct. 9, 1950. *Oil Gas J.,* **49,** 79-81+ (1950) Oct. 26.

Answers are given to questions such as what can be determined from fatigue studies, how about care in handling, and how serious is the permanent damage. Practically all drill-collar failures are the result of fatigue at the connections. Box failures are the result of corrosion fatigue and can be prevented by protection against corrosion. Pin failures are the result of certain poor operating practices which cause over-stressing. Most pin failures can be avoided if a few extremes in operating practice are recognized and eliminated. A simple set of rules is presented.—INCO.

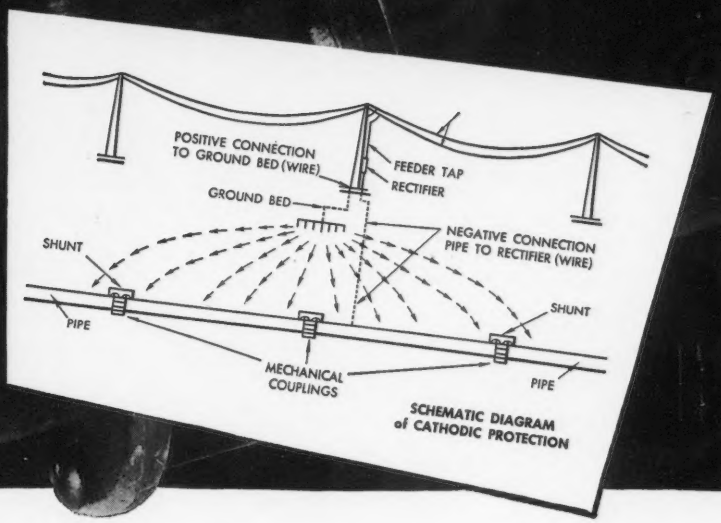
8.8 Group 8

8.8.1, 6.5

Phenol by Sulfonation—A Staff-Industry Collaboration Report. R. L. Kenyon in collaboration with N. Boehmer. Monsanto. *Ind. and Eng. Chem.,* **42,** No. 8, 1446-1455 (1950) Aug.

In general, equipment throughout the plant is steel or cast iron. At points where wet sulfur dioxide is handled, Tobin bronze, lead or Haveg is used. Sodium benzenesulfonate solutions, containing small amounts of sulfur dioxide, are handled in Everdur. Nickel is used in pumps and pipes for caustic solution. Stainless steel 304 is used for the hot slurries of sodium sulfite, which has both an abrasive and corrosive action. The centrifugal separators are of stainless steel for this reason. Cast iron gives satisfactory service where sulfonic acid is used, as in the sulfonators. It is well known that iron causes discoloration of phenol. For this reason, nickel is used in handling the finally distilled product, beginning with the condensers. Steel may be used for storage and shipping where a water-white product is not required.—INCO.

PIPE COUPLING SHUNTS for *Cathodic Protection* of Pipe Lines



The U·S·S American Pipe Coupling Shunt consists of a rectangular copper bar flash-butt welded to steel terminals shaped to fit the curvature of the pipe. A secondary steel wire fits onto the same terminals for welding to the middle ring of the coupling (as shown) to keep the potential of this ring the same as that of the pipe. This wire can also be tacked to the follower rings.

CATHODIC Protection is a superior method of preventing corrosion. It consists basically of raising the DC potential of the earth around the pipe line so that electric current flows from the earth to the pipe. The current is then drained from the pipe line at intervals through electrical conductors firmly bonded to the pipe and connected back to current supply. But all sections of the pipe must be at the same potential.

For pipe lines employing mechanical couplings, a special shunt has been developed by engineers of American Steel & Wire. This assures a firm bond between all sections of pipe to be protected. The shunt has steel terminals so that it can be easily welded to steel pipe with steel electrodes. This weld is easy to make, strong, and permanent. The shunt provides an easy means for low-cost permanent bonding between pipe sections.

For complete information on U·S·S American Pipe Coupling Shunts, Coupon and Galvanic Anode Connectors, write to American Steel & Wire, Rockefeller Building, Cleveland 13, Ohio.

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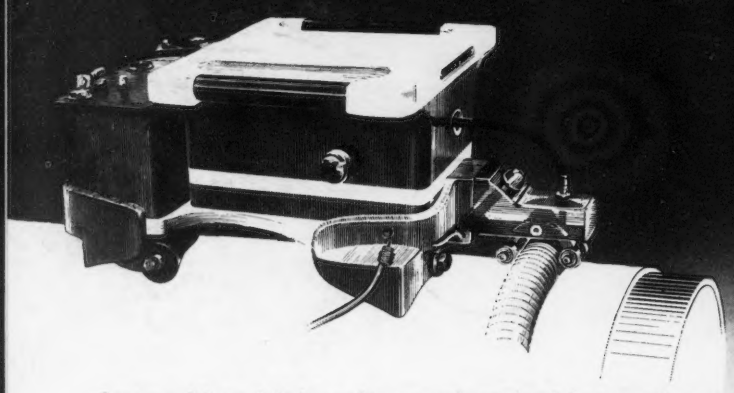

The STEARNS ELECTRONIC HOLIDAY DETECTOR* is a device for making high voltage electrical inspection of pipe line coatings, above ground, as the unit is rolled along on the coated pipe by an operator. The complete Unit consists of the Generator coupled with an Alarm System, the Rolling Coiled Spring Exploring Electrode and Pusher Carriage Assembly. A small 6-volt storage battery serves as the power source.

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Fundamental precepts which are met by the Stearns Detector are:

(1) To generate a high voltage pulse of short duration regulated to hold the crest *intensity* within narrow limits irrespective of pipe size and the variable moisture conditions experienced during field inspection;

(2) To cause such a pulse to re-occur at a *rate* rapidly enough so as to have entirely traversed the coating surface with successive overlapping circumferential bands of ionization as the testing electrode is moved along the coated pipe;

(3) To *apply*, in a simple manner, these testing pulses to the coating by means of an exploring electrode embracing and self-conforming to the variable shape of the exterior of the coated pipe while being held in electrically effective contact with the coating surface at all times; and

(4) To give out audible and visual alarm signals as an instantaneous response actuated by the formation of a spark between electrode and pipe upon encountering a fault in the coating.

Under these principles the Stearns Detector in operation approaches the ideal in testing technique, with maximum safety to the operator, by providing thorough one-pass coverage while uniformly subjecting the coating only to the extent of electrical stress necessary to ensure complete inspection.

LIGHT WEIGHT

The Stearns Detector is fabricated from the lightest materials available having the required mechanical and electrical strength. The complete unit weighs 28 pounds—is 13.5″ long, 9″ wide, 7.5″ high. A welded magnesium case for the Detector, and a wooden box for two 10 pound 6-volt batteries serve as sturdy containers for storage and shipping. The complete shipping weight, including an overnight battery charger, is 75 pounds.

SIMPLE TO OPERATE

The Stearns Detector can be operated without special training or experience on pipes of all sizes. The proper output voltage is set before shipment and the regulation is thereafter automatic—all functions of the Detector being controlled by a single 'On'-'Off' switch. The patented pulse generator, which makes possible such automatic voltage regulation, is an exclusive feature of the Stearns Detector.

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The Stearns Detector has been developed through eleven years of field experience and continued research and has become the Standard of the Industry. All major parts of the high voltage generating circuit are custom built for their specific functions and fitted together into an electrical assembly of proved dependability. Users of Stearns Detectors are constantly ensured of receiving equipment in new condition as a result of the rigid shop and laboratory maintenance procedures followed by The D. E. Stearns Company.

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